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THE JOURNAL
OF
THE INSTITUTION OF ELECTRICAL ENGINEERS

ISSUED IN THREE PARTS

PART I. GENERAL (*Monthly*) PART II. POWER ENGINEERING (*Alternate Months*)
PART III. COMMUNICATION ENGINEERING (*Quarterly*)

PART I. GENERAL

CONTENTS

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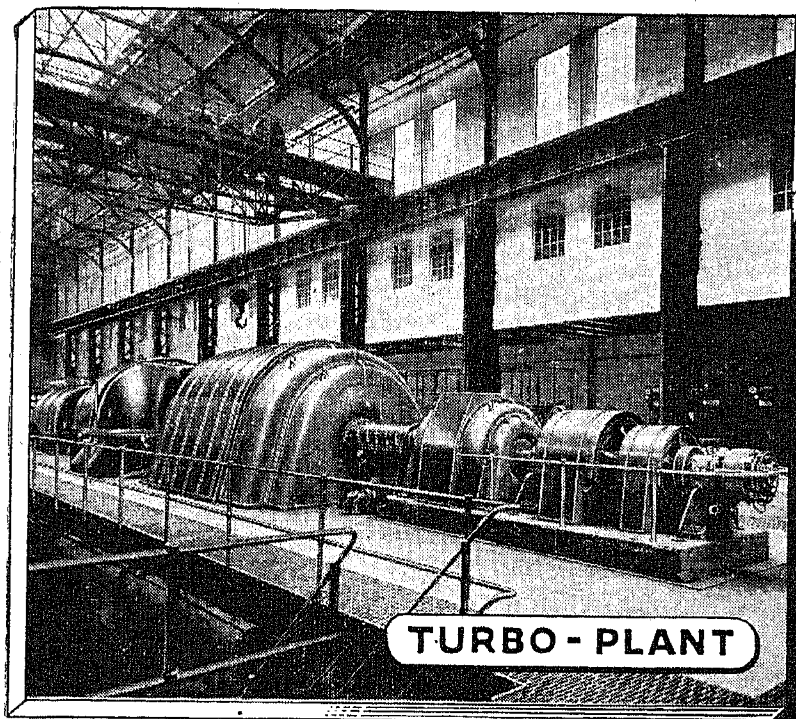

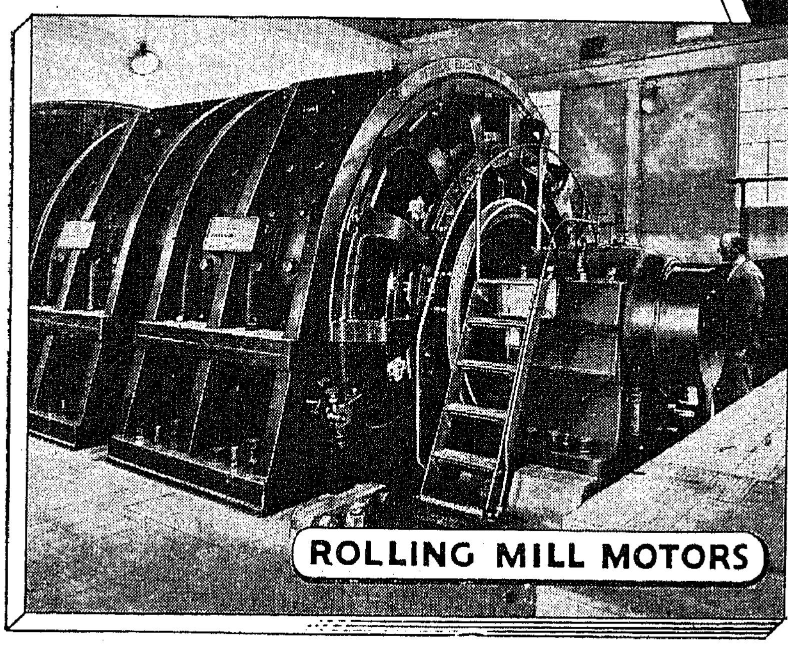

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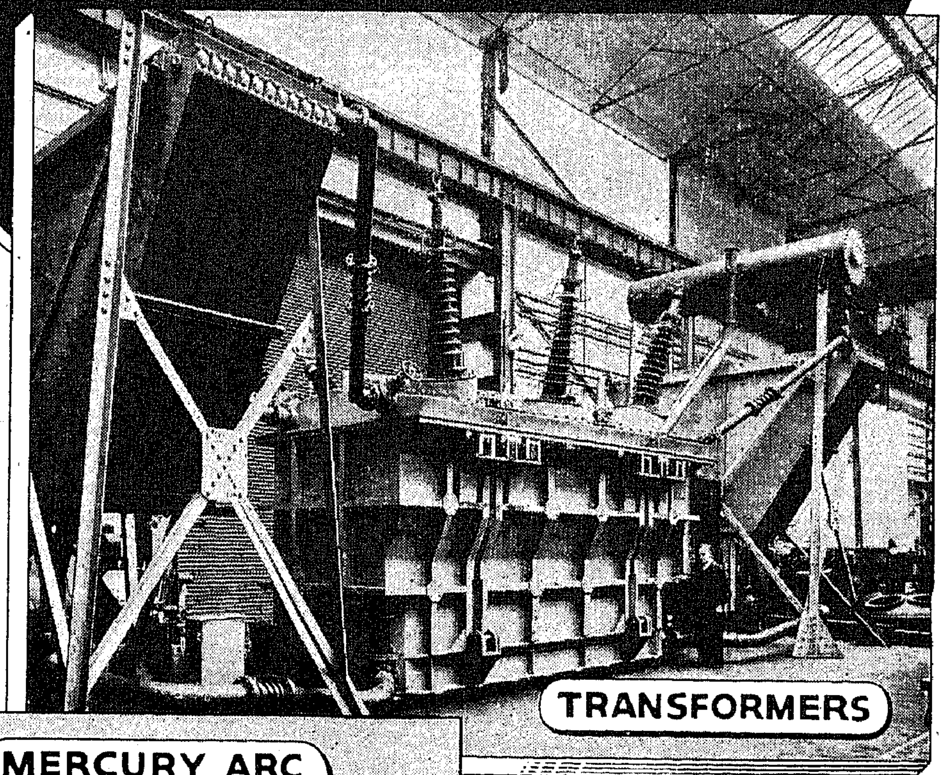

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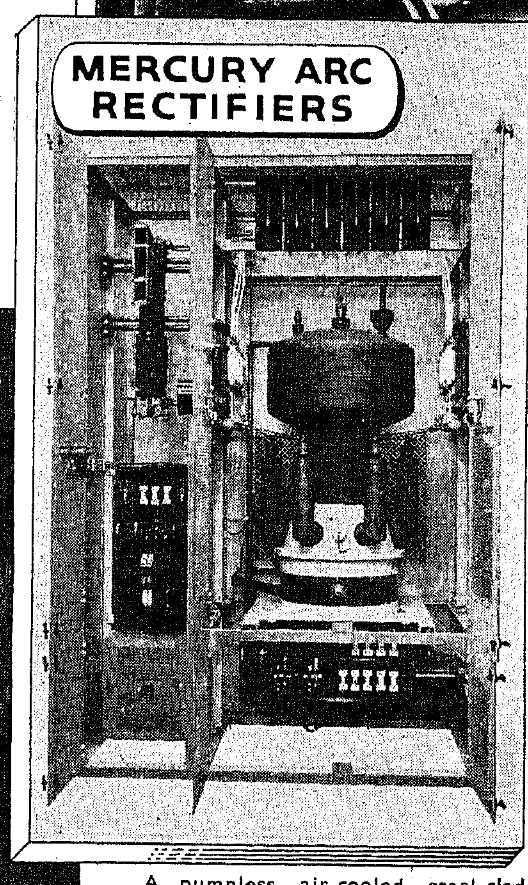

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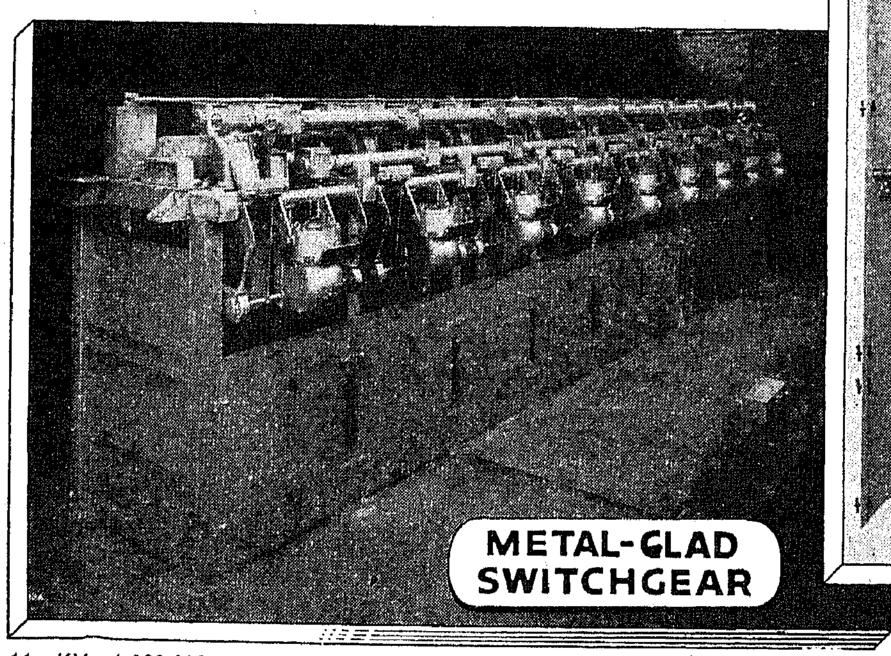

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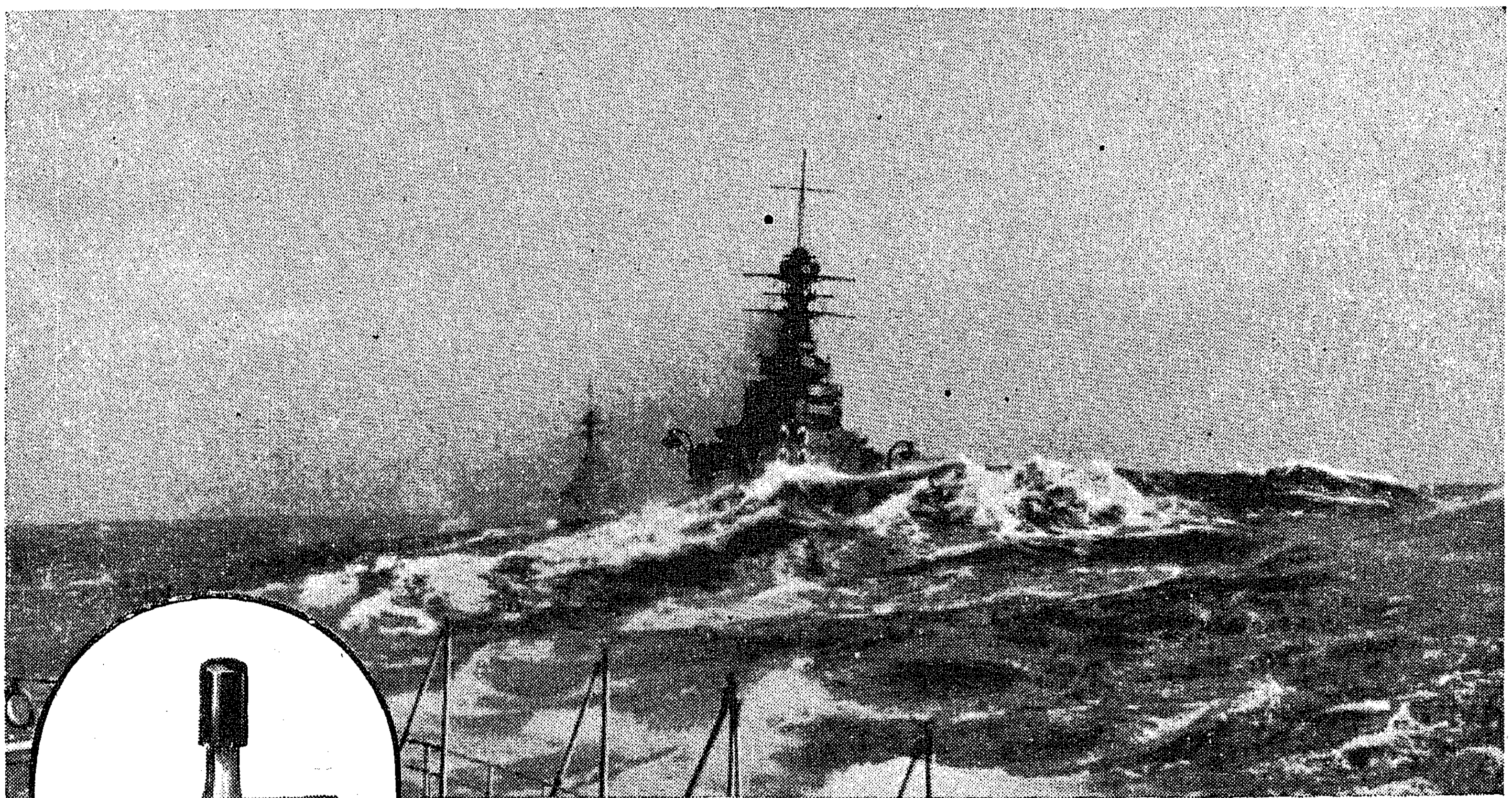

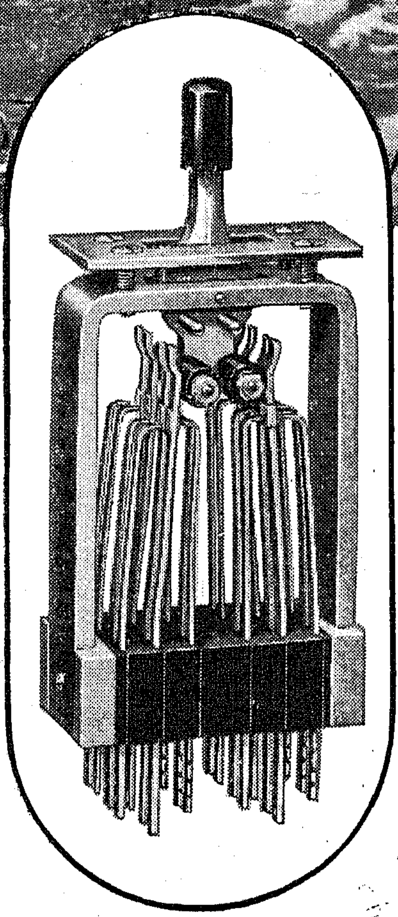

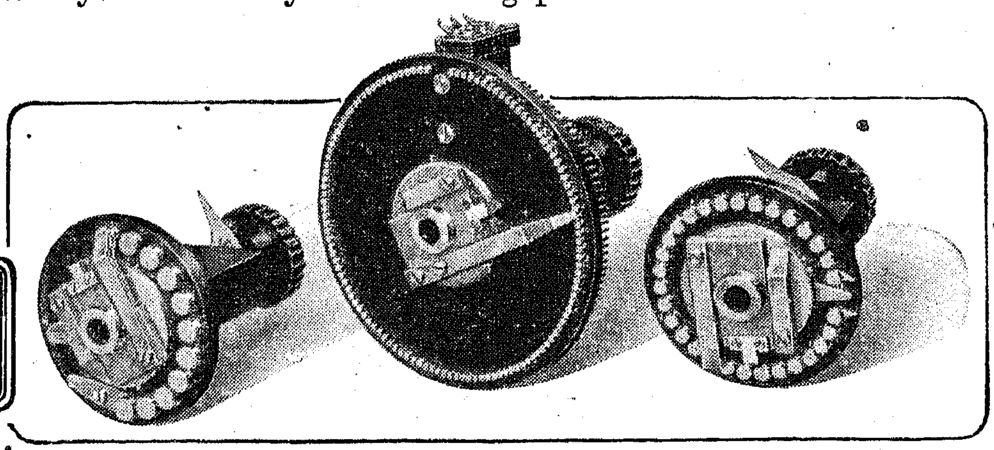

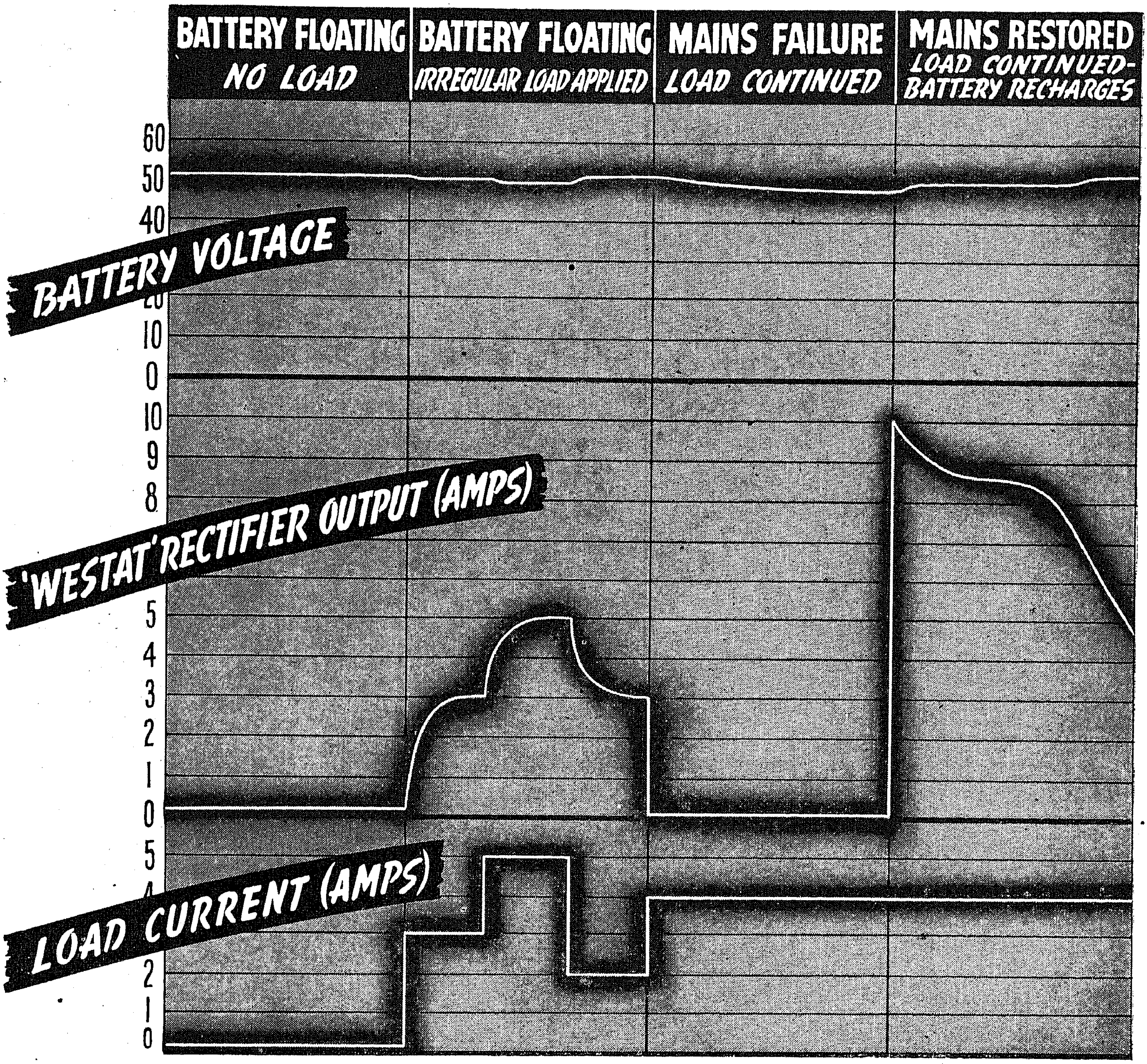
BATTERY FLOATING
NO LOAD
BATTERY FLOATING
IRREGULAR LOAD APPLIED
MAINS FAILURE
LOAD CONTINUED
MAINS RESTORED
LOAD CONTINUED-
BATTERY RECHARGES
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LOAD CURRENT (AMPS)

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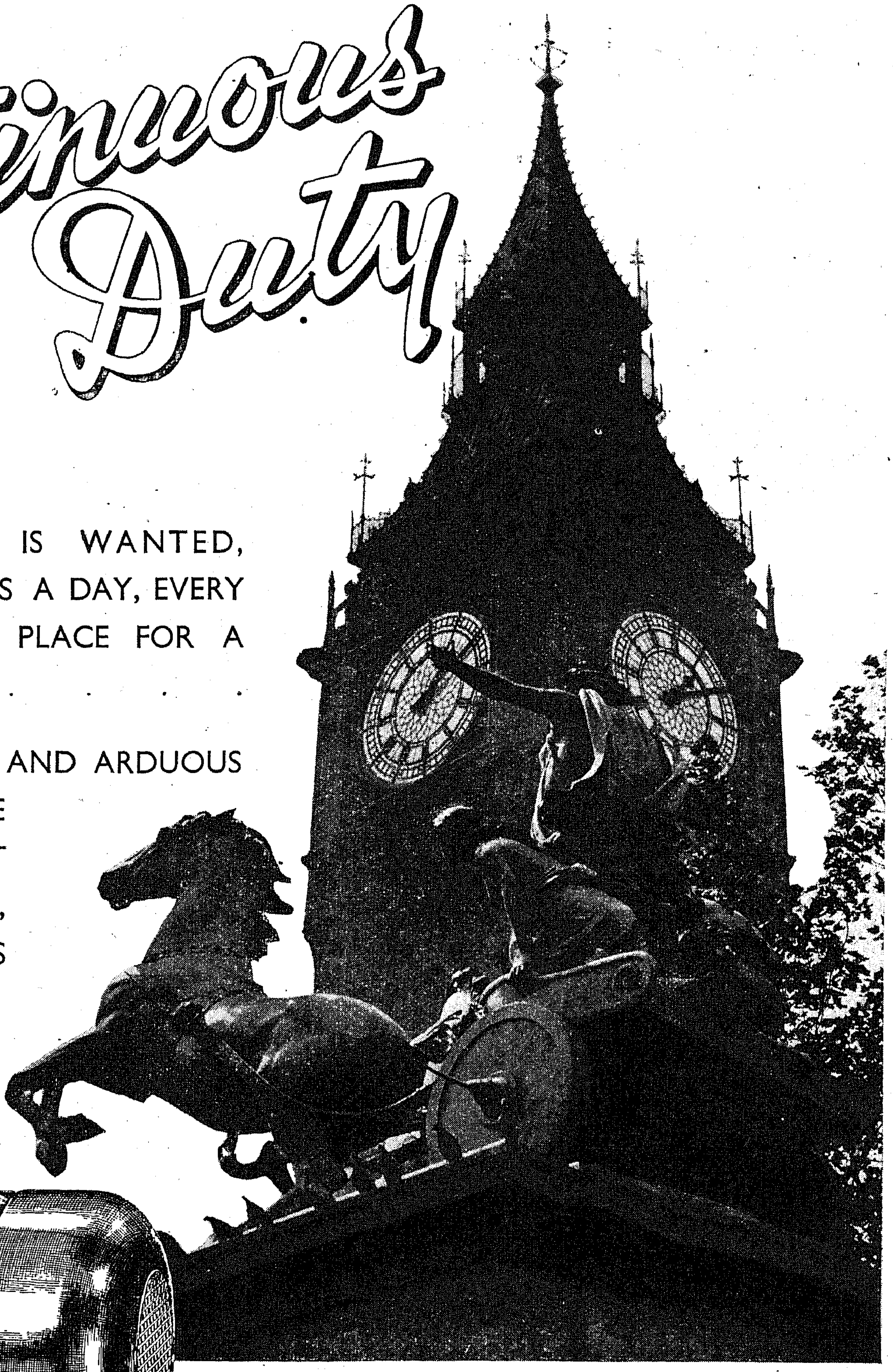

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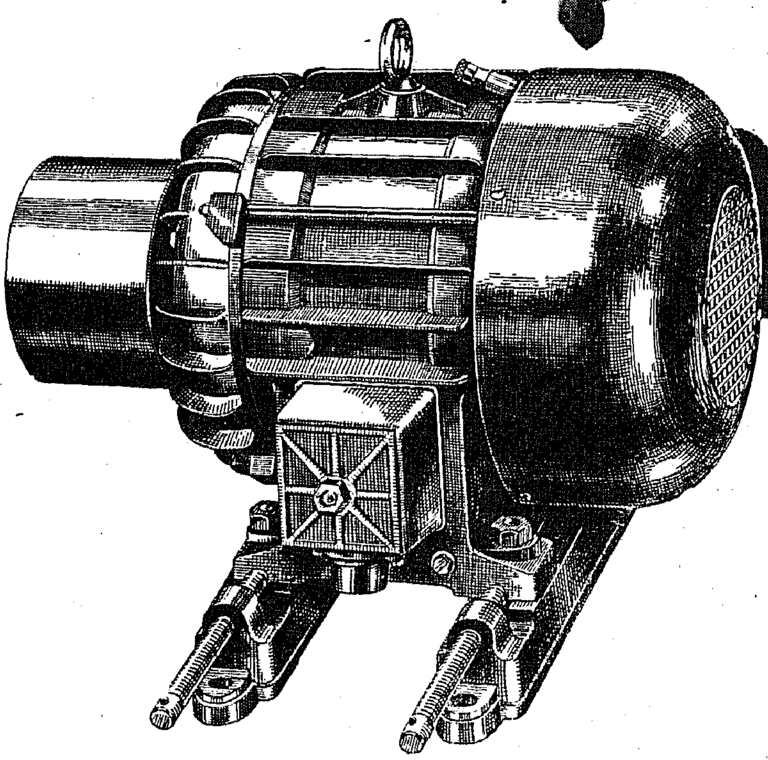

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The Hackbridge Company is fully conscious of the fact that the world-wide reputation enjoyed by Hackbridge Transformers demands continual vigilance in every stage of design and manufacture.

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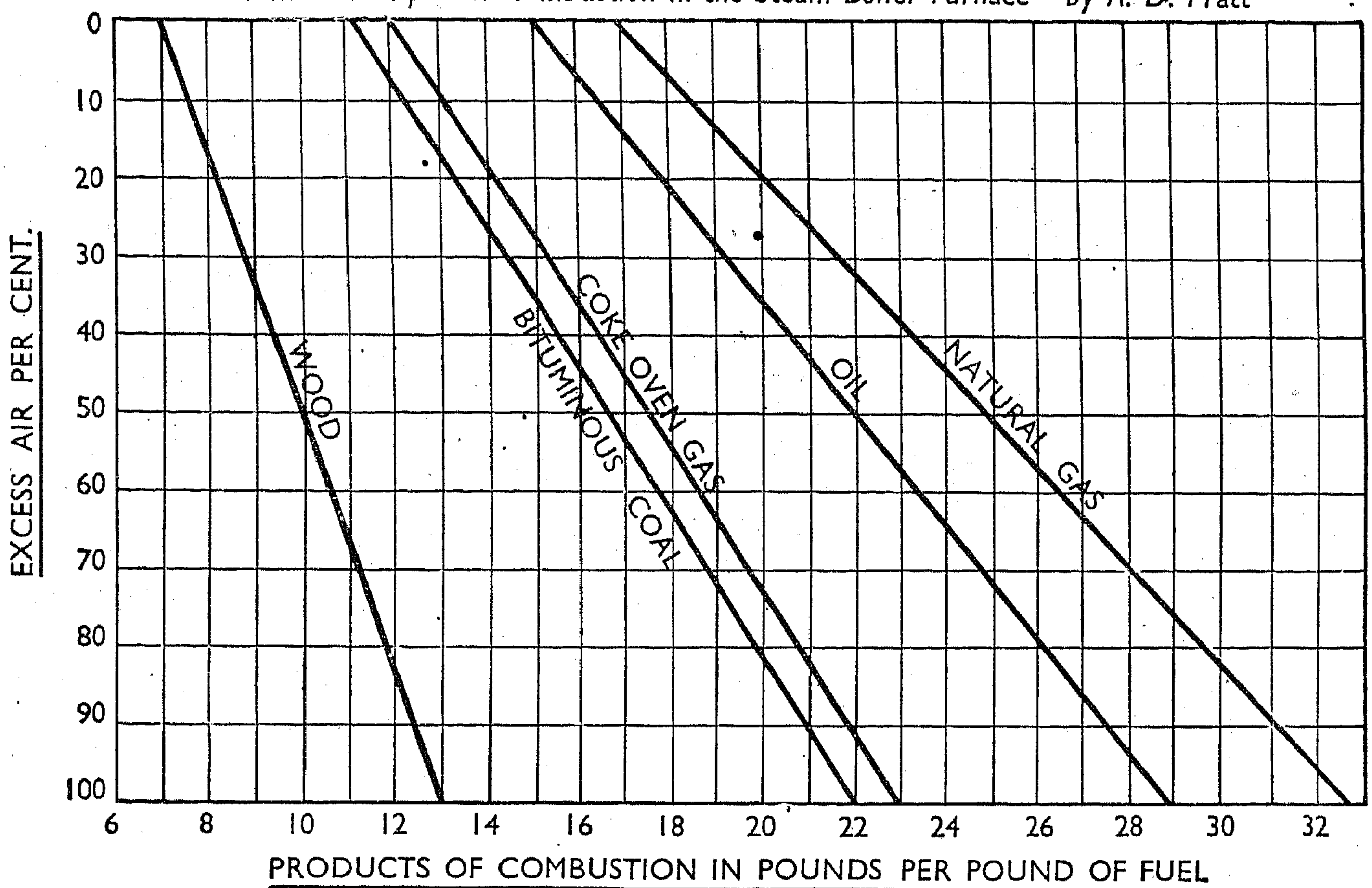
What does CO_2 mean?

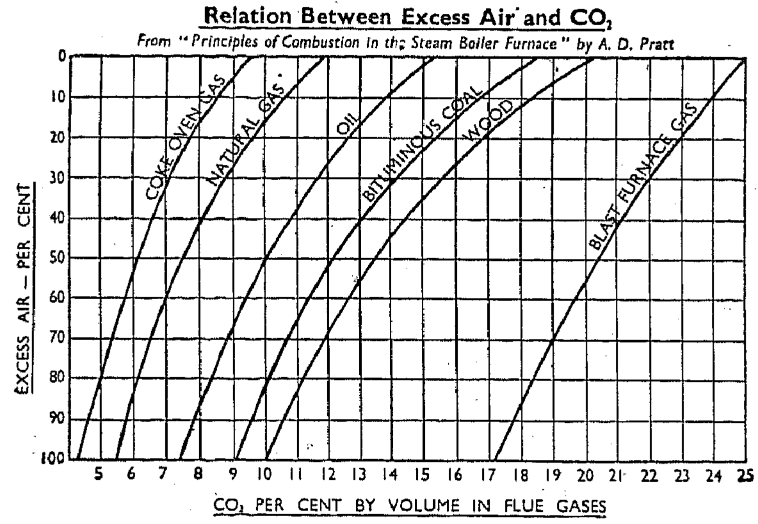
Relation Between Excess Air and Products of Combustion

From "Principles of Combustion in the Steam Boiler Furnace" by A. D. Pratt



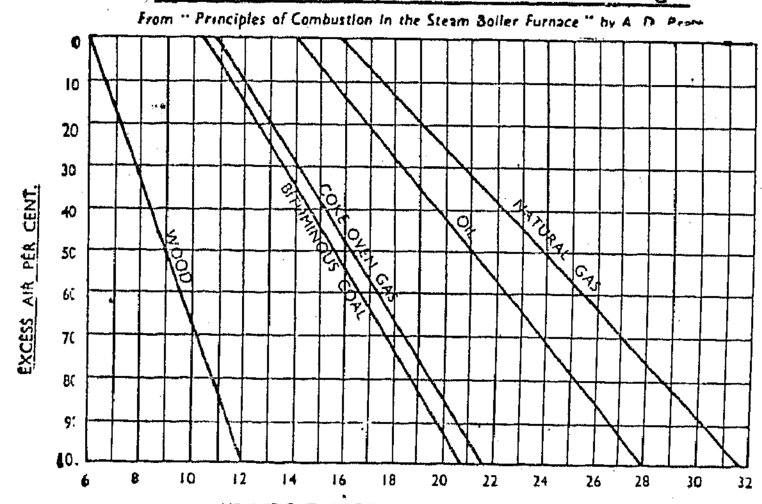
Relation Between Excess Air and CO_2

From "Principles of Combustion in the Steam Boiler Furnace" by A. D. Pratt



Relation Between Excess Air and Air Weight

From "Principles of Combustion in the Steam Boiler Furnace" by A. D. Pratt



FROM the above chart it will be seen that when burning 1 lb. of coal, an increase from 20% to 100% excess air means that the weight of the products of combustion is increased by approximately 8½ lb.

Our previous advertisement showed that this increase in excess air involved an increase in the weight of air for combustion by the same amount. Thus the forced draught and the induced draught fans together must handle approximately 17 lb. more air and products of combustion than that necessary for efficient combustion.

In the case of a boiler for 175,000 lb. of steam per hour, with 20% excess air the fan motors would be rated at 196 h.p., which would be increased at 100% excess air to 875 h.p. thus involving an increase in electrical input to the motor terminals of 570 KW. Assuming 20 hours per day and 300 days per year, at ½d. per KWH this unnecessary expenditure in fan power amounts to £7,130 per annum, which in itself is more than sufficient to pay for a Bailey furnace. This sum capitalised at 4% interest for 20 years amounts to over £212,000. Bailey furnace construction permits operation with minimum excess air over a very wide range of load, so that the saving in fan power debit alone gives a very handsome return on capital invested.

Criticism might be made that the limits are too wide in the foregoing example, but even if operation is assumed with 60% excess air, then the unnecessary fan power expenditure is £2,840 per annum, which when capitalised amounts to £84,570. However, when it is realised that this fan power debit is one of the smallest items entering into the balance sheet, it will be obvious that Bailey furnace construction is in the last analysis the cheapest construction which can be installed.

(For convenience we reproduce the charts from our Nos. 1 and 2 advertisements in this series, showing the relationship between excess air and CO_2 and weight of air for combustion.)

This is the third of a series of three advertisements

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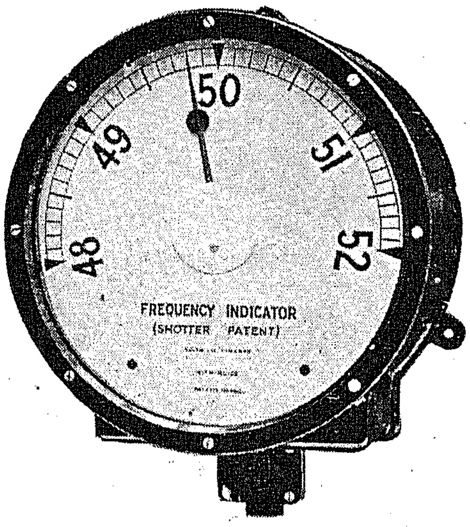

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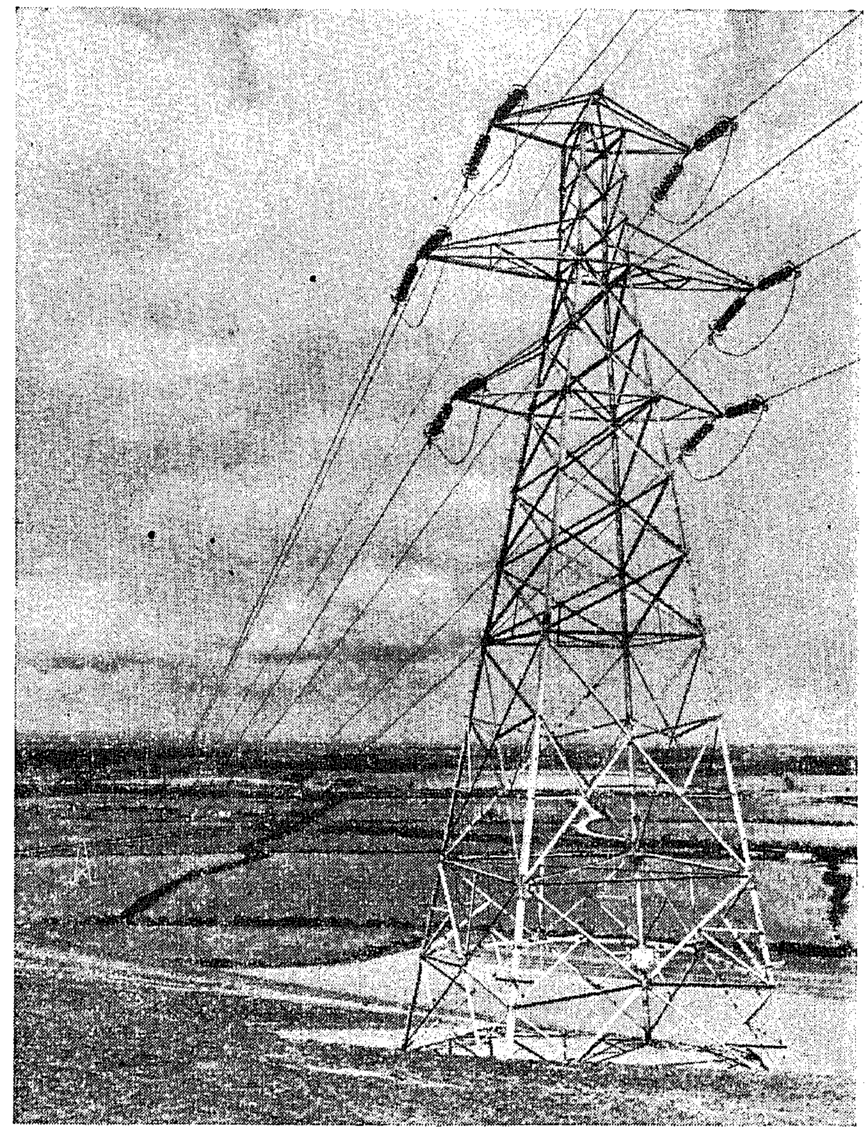

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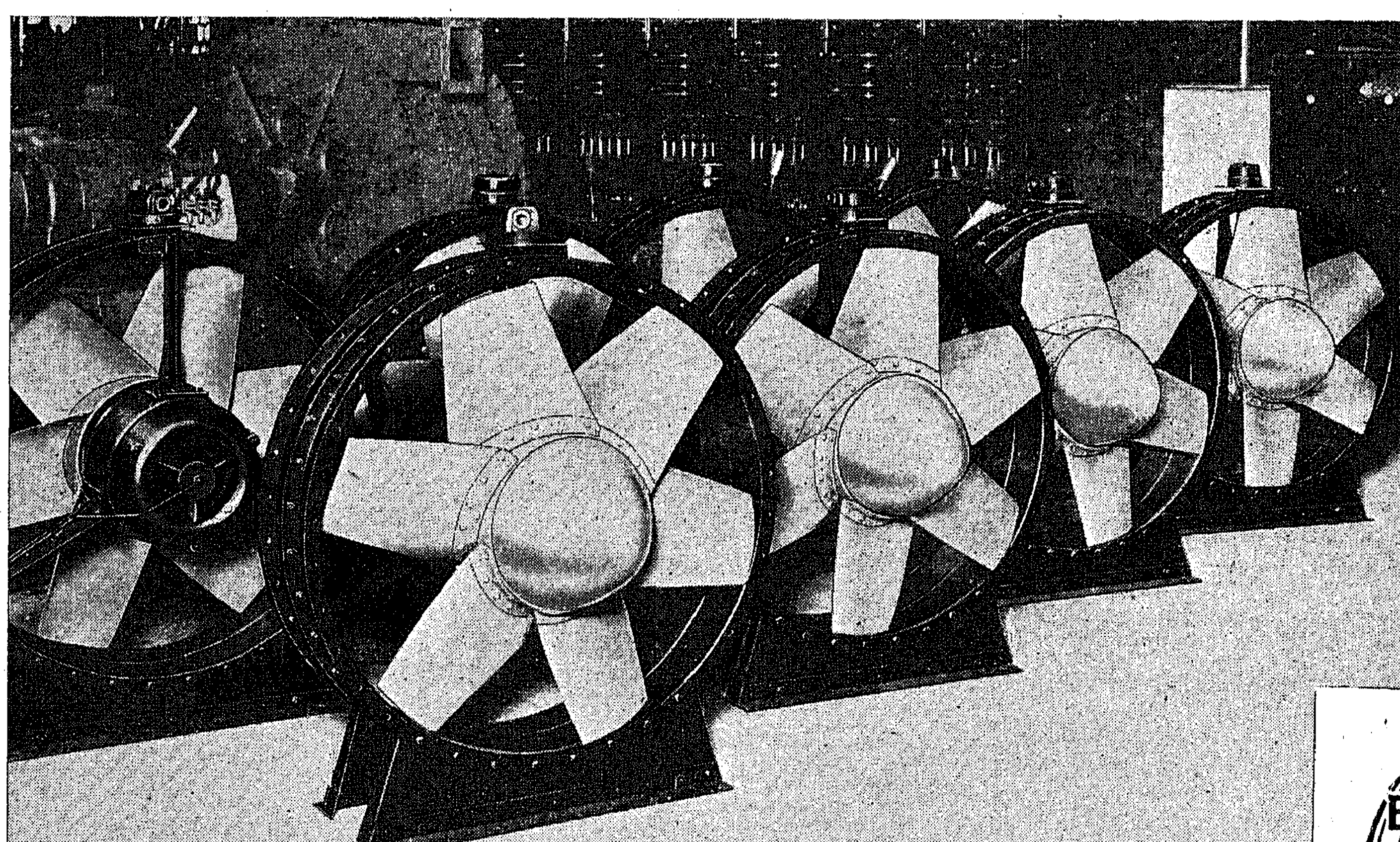

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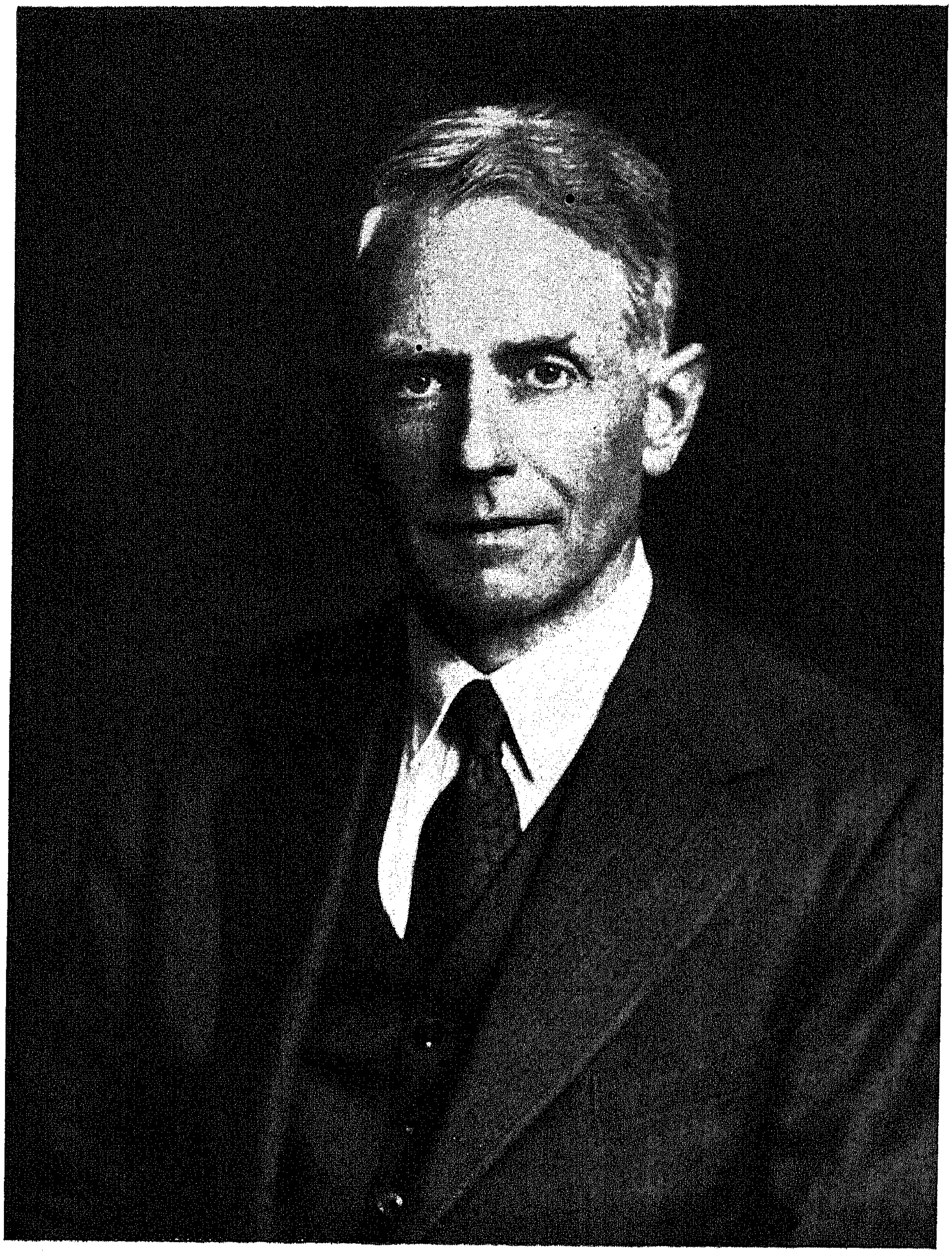

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THE JOURNAL OF

THE INSTITUTION OF ELECTRICAL ENGINEERS

EDITED BY W. K. BRASHER, SECRETARY

VOL. 88. PART I (GENERAL). No. 1. JANUARY 1941

FOREWORD TO THE NEW JOURNAL

By J. R. BEARD, M.Sc., President.

This number of the *Journal* inaugurates the new method of publication which was described in the circular letter sent to members last summer after the paper shortage had become acute and paper rationing had been introduced. Since then the paper situation has deteriorated further and the need for economy has increased. Economy is also necessary in the interests of The Institution's own finances owing to the considerably increased cost of paper, production and postage. It is satisfactory to be able to record that the response to the circular letter showed that the new arrangements met with the general approval of members.

Now that the re-arrangement is an accomplished fact, it remains to be seen whether this general approval of members will still be forthcoming. Personally I think that it will, because I feel sure that the change in form of the *Journal* has much greater justification than merely saving paper and preventing undue increase in the cost of publication.

For some years past it has been increasingly felt that much of the material in the *Journal* has tended to become of a highly specialized character and therefore of interest to only limited sections of the membership. By distributing the full proceedings to every member, individual members received rather a forbidding bulk of highly technical matter of which only a proportion was of direct interest to them, and even that was made difficult of approach by being cumbered with other matters.

The new arrangement recognizes this difficulty by subdividing the *Journal* into three Parts. Part I, "General," is designed to include all matters likely to be of general interest to all members, including abstracts of all papers and "Institution Notes" through which members will be kept informed of the activities of The Institution. It is to be issued monthly and all members will receive it free. Parts II and III will include in full all specialized papers on "Power Engineering" and "Communication Engineering" respectively, thus giving recognition to the two main fields of electrical engineering activity. It is these two Parts for which members must apply specially and for which it is at present found necessary to make the small additional charge of 7s. 6d. per Part per annum (reduced to 2s. 6d. for Students and Graduates up to the age of 28). These Parts are to be issued less frequently than Part I; Part II in alternate months and Part III quarterly.

As free advance copies of papers accepted for reading at meetings will still be available, members will be in a position to obtain copies of individual papers to be published in a Part to which they do not subscribe. A request for a free copy of a paper after it has been read at a meeting will also be met in so far as surplus copies are available.

Members of the Wireless Section will find that Part III incorporates the "Proceedings of the Wireless Section" and that this is indicated in the sub-title. It also includes papers on telegraphy and telephony; these are comparatively few and will probably be of interest to members of the Section.

The new feature which has been introduced into Part I, of giving abstracts of all papers which are published in Parts II and III, will, it is felt, be of considerable value to all members. These abstracts will be sufficiently complete to indicate the nature and scope of the papers and to enable members to decide whether any paper is of sufficient interest to them to justify reference to the full paper. The abstracts will also be designed to bring out the main principles for the benefit of those members who have no specialized knowledge of the subjects of the papers.

This re-arrangement of the *Journal* was adopted after most careful consideration and the Council hope that it will be justified by experience, but they fully recognize that it must be subject to reconsideration and modification from time to time to meet the requirements of our members as more experience is obtained of it.

INSTITUTION NOTES

ARRANGEMENTS FOR THE SECOND HALF OF THE SESSION

As already announced in the December issue of the *Journal* the Council have decided that under the prevailing conditions it would be inadvisable to hold meetings of The Institution in London during the second half of the session. A list of the papers that would in normal circumstances have been included in the programme of meetings is given below, and advance copies of these papers can be obtained on application to the Secretary by members who contemplate the submission of written contributions for publication in the *Journal* as a discussion with the author's reply.

The approximate dates on which the advance copies will be available are shown in the list, together with an indication in parentheses of the Parts of the *Journal* in which the papers will be published in full. Abstracts of all the papers published in Parts II and III will appear in Part I.

Separate application should be made for each paper that a member may require, and it is hoped that, in the interests of economy, members will apply for only those papers to the discussion of which they are likely to contribute.

List of Papers allocated for discussion, of which a limited number of advance copies will be available about the dates indicated.

Author	*Title of Paper, and Part in which it will appear*	*Copies available*
W. J. Mason and S. A. G. Emms	"Electricity in Paper Mills" (Part II)	1 Feb.
B. J. Edwards	"The Design of Television Receiving Apparatus" (Part III)	5 Feb.
Alwyn Evans	"The Electricity Supply (Meters) Act, 1936—its Legal and Technical Implications" (Part II)	7 Feb.
W. A. Cook, B.Sc. (Eng.)	"Outdoor Bushings for Transformers and Oil Circuit-Breakers" (Part II)	12 Feb.
P. Schiller	"The Future of Domestic Electrification" (Part II)	20 Feb.
F. C. Williams, D.Sc., D.Phil.	"The Fluctuations of Space-charge-limited Currents in Diodes" (Part III)	5 Mar.
C. E. R. Bruce and R. H. Golde	"The Mechanism of the Lightning Discharge and its Effect on Transmission Lines" (E.R.A. Report S/T18) (Part II)	20 Mar.
A. Fairweather, M.Sc., and J. Ingham, M.Sc.	"Subsidence Transients in Circuits containing a Non-linear Resistance, with reference to the Problem of Spark-quenching" (Part II)	24 April

ORDINARY MEETING, THURSDAY, 30th JANUARY, 1941, at 12.30 p.m.

A formal Ordinary Meeting of The Institution will be held on the above date for the purpose of carrying out a ballot in respect of the candidates whose names were presented at the Ordinary Meeting held on the 2nd January, 1941. (Only Corporate Members and Associates are eligible under the Bye-laws to participate in the ballot.)

KELVIN LECTURE AND ANNUAL GENERAL MEETING, 8th MAY, 1941

It is proposed to arrange for the Kelvin Lecture by Dr. S. Chapman, F.R.S., to be delivered at 3 p.m. on Thursday, 8th May, 1941, immediately following the Annual General Meeting which is to be held on that day at 2.30 p.m. The title of the Lecture will be "Electrical Works by Helios: the Sun and the Ionosphere."

WIRELESS SECTION PREMIUMS

The Council have decided that the name of Ambrose Fleming shall be associated in future with one of the £10 Premiums awarded annually for papers presented to the Wireless Section.

JOURNAL

Commencing with the current volume, roman type similar to that used by *The Times* newspaper has been adopted for the *Journal*. This was selected by *The Times* a few years ago after extensive research and investigations on the legibility of various letterpress.

SCIENCE ABSTRACTS

Commencing with the 1941 Volumes, the title of *Science Abstracts* shown on the covers of the publication will be supplemented by "Physics Abstracts" and "Electrical Engineering Abstracts" respectively for Sections A and B. The additional titles will precede the present title.

The page size of the publication is also being increased at the same time so that it is uniform with that of the *Proceedings of the Royal Society*. "Times" type similar to that just adopted for the *Journal* will also be used.

MEMBERS FROM OVERSEAS

The Secretary would be glad if members coming home from overseas would inform him whenever possible in advance of their visit, stating their address in this country even if they do not wish a change of address recorded in the Institution Register.

The object of this request is to enable him to advise members visiting this country of the meetings and functions of The Institution and its Local Centres and, when occasion arises, to put them into touch with other members.

The Secretary would also be pleased to receive visits from overseas members and to assist them in any way possible during their stay in the United Kingdom.

COMMUNICATIONS FROM OVERSEAS MEMBERS

Overseas members are especially invited to submit, for publication in the *Journal*, written communications on papers read before The Institution or published in the *Journal* without being read. The contributor's country of residence will be indicated in the *Journal*. In this connection a small number of advance copies of all papers read before The Institution are sent to each Local Honorary Secretary abroad to enable him to supply copies to members likely to be in a position to submit communications.

I.E.E. MODEL FORM OF GENERAL CONDITIONS FOR CONTRACTS

The Council have approved for publication a revised (December, 1940) edition of the above General Conditions C for the sale of goods other than cables, at home, without erection. Copies may be obtained from the Secretary of The Institution or from Messrs. E. and F. N. Spon, Ltd., 57, Haymarket, London, S.W.1, price 9d. each (postage extra).

No additional clauses have been published for use with these Conditions C during the present war.

LOCAL CENTRE ACTIVITIES

It is satisfactory to record that despite the preoccupations immediately arising from the important part which members throughout the country are taking in the war effort, some of the Local Centres and Sub-Centres are finding it possible to help maintain the Institution's tradition by holding the usual meetings for the discussion of papers, or for informal discussions on subjects of topical interest. In some instances it has been possible to arrange for the customary sessional programme, whilst in others a skeleton programme is being carried out with success. Unfortunately such activities have not been found to be practicable in every Centre and Sub-Centre, some Local Committees having felt compelled, owing to prevailing conditions, to suspend their usual meetings in the same way as has been found necessary in London.

In the present circumstances, especially as it has not been practicable to issue the customary combined Meetings Programme this session, it may be of interest to record here some of the current activities in the provinces. The following brief notes therefore, though not purporting to be a complete record of activities, will serve to indicate the persevering efforts of the Centres and Sub-Centres to carry on the work of The Institution wherever possible.

Irish Centre.

The activities of this Centre are substantially on normal lines, a series of five meetings, at approximately monthly intervals, having been arranged, commencing with one in December. Four of the papers to be discussed are being provided by members connected with the Electricity Supply Board; at the meeting arranged for the 16th January Messrs. P. Taylor, B.E., and W. Cronin, B.E., will read a paper on "Steam Generators."

Mersey and North Wales (Liverpool) Centre.

The Centre Committee decided that for the present the usual programme of meetings could not be held, but on Saturday afternoons two successful meetings have taken place, one at Liverpool and the other at Chester, at both of which the Address of the Chairman, Mr. J. E. Nelson, was delivered. The Address will appear in the February issue of the *Journal.*

Two of the papers that would have been discussed at Liverpool if the customary programme had been in operation have also been included in the programme of the North-Western Centre, the Committee of which have issued a general invitation to all members of the Liverpool Centre who are able to make the journey to attend any of the Manchester meetings held throughout the session.

The Centre Committee are bearing in mind the question of a resumption of meetings in the New Year should conditions appear suitable; and it is the intention to arrange if possible for the Faraday Lecture by Mr. C. E. Fairburn on "Electric Traction" to be delivered in March.

During the first half of the session the Liverpool Students' Section have tried with some success to hold meetings on Saturday afternoons, and the Section Committee hope to arrange a limited number of similar meetings for the remainder of the session if it is found impossible to resume a more normal programme.

North-Eastern Centre (and Tees-Side Sub-Centre).

During the first half of the session the usual programme of meetings in Newcastle-upon-Tyne has been substantially maintained, and it is hoped to be able to continue in this way for the remainder of the session, a full programme of meetings having been provisionally arranged. Four meetings have so far been held, at the first of which the Address of the Chairman, Mr. W. A. A. Burgess, was delivered.

Instead of the usual meeting-place at Newe House, all meetings except the first have been held at Neville Hall (the home of the North of England Institute of Mining and Mechanical Engineers) where suitable air-raid shelter accommodation is available.

An interesting addition to the programme was provided by an invitation from the North-East Coast Institution of Engineers and Shipbuilders to the Centre members to attend the Parsons Memorial Lecture delivered in December by Sir Stephen J. Pigott on the subject of "The Engining of Highly Powered Ships."

The Centre Committee hope that it will be possible to arrange for the Faraday Lecture by Mr. C. E. Fairburn on "Electric Traction" to be given later in the session.

The Address of the Centre Chairman, Mr. Burgess, was also delivered in November at a meeting of the Tees-Side Sub-Centre, the Committee of which have decided to hold meetings monthly throughout the session. The programme commenced with the Address of the local Chairman, Mr. T. S. G. Seaward. Both Addresses will appear in due course in the *Journal.*

The North-Eastern Students' Section, which meets in the same hall as the parent Centre, are continuing their customary fortnightly meetings, and in November created a record at their Annual Dance by an attendance of no less than 330.

North Midland Centre (and Sheffield Sub-Centre).

Three meetings of the Centre have so far been held, at the first of which an informal lecture was delivered by Mr. J. W. Howell, of the E.L.M.A. Service Bureau.

All these meetings have taken place on Saturday afternoons, and it is hoped to arrange three further meetings in addition to the Annual General Meeting during the second half of the session. The practice of holding meetings on Saturday afternoons has also been adopted by the North Midland Students' Section, whose opening meeting took place in November, at which the address of the Section Chairman was followed by a general conversazione.

The Sheffield Sub-Centre have also found it possible to arrange a programme of afternoon meetings. The first of these, in October, was devoted to the Address of the Chairman, Mr. F. C. Clarke, who in addition opened a

discussion at a meeting in November, when the subject of "Recruitment and Training for the Engineering Industry" was dealt with. Mr. Clarke's Address will be published in March in the *Journal.*

The Sheffield Students' Section are, like the Sub-Centre, carrying on their activities, a programme substantially on the lines of their normal one being followed. The meeting held on the 8th January was a joint one with the Yorkshire Graduates' Branch of The Institution of Mechanical Engineers.

North-Western Centre.

A regular programme of monthly meetings is being carried out, the only change from normal arrangements being that the meetings take place on Saturday afternoons. The programme was opened in October with the Address of the Chairman, Mr. B. A. G. Churcher, which will be published next month. At the November meeting Mr. Churcher, with his co-author, Mr. A. J. King, presented their paper entitled "The Limitation of Transformer Noise" (see the November 1940 issue of the *Journal*). At the invitation of the Committee this meeting was the occasion of a formal visit by Mr. V. Z. de Ferranti in his capacity as a Vice-President of The Institution.

Mention has already been made of the general invitation issued by the North-Western Centre Committee to the members of the Liverpool Centre to attend any of the Manchester meetings, should travelling conditions permit.

Members of various kindred Associations in the Manchester district were invited to attend the December meeting when the paper by Messrs. E. Fawssett, H. W. Grimmitt and G. F. Shotter and Dr. H. G. Taylor, entitled "Practical Aspects of Earthing," which was published in the October issue of the *Journal*, was discussed. Mr. Fawssett and Dr. Taylor attended the meeting to present the paper.

The activities of the North-Western Students' Section have been well maintained so far this session, regular monthly meetings having been held on Saturday afternoons, and it is hoped to be able to continue these arrangements for the rest of the session.

Scottish Centre (and Dundee Sub-Centre).

Five meetings of the Centre have been held up to date, three of these in Glasgow and the remainder in Edinburgh. All these meetings have been held jointly with the Scottish Students' Section, who have thus been able to maintain the Section activities by co-operating with the parent Centre.

An unusual but specially interesting feature of the programme was a talk entitled "Reminiscences" given by Prof. F. G. Baily at Edinburgh. Prof. Baily's talk, repeated at Dundee in December, formed part of the programme arranged by the Dundee Sub-Centre, which it is hoped will consist of four meetings during the session, either for the delivery of lectures or for informal discussions. At the November meeting, to which the members of the Dundee Institute of Engineers were invited, the subject of "Man Power and The Machine" was discussed.

South Midland Centre (and East Midland Sub-Centre).

The Centre Committee, after careful consideration, regretfully came to the decision "That owing to the exigences of the national situation it is not deemed desirable or even feasible to arrange meetings until the situation becomes more clear." The Committee have every intention, however, and are indeed most anxious, to resume the Centre meetings as soon as this is found to be practicable.

Two meetings of the East Midland Sub-Centre have so far been held and two other meetings have been arranged for the rest of the session. These will be held at 2.15 p.m. on the 29th January and the 26th March.

At the meeting in October, which took place at Loughborough, the Address of the Chairman, Captain B. Croft Bayley, was delivered. It will appear in the March issue of the *Journal.*

A very successful meeting held at Nottingham in December, at which a Discussion on "Electricity in Agriculture" was opened by Mr. H. W. Grimmitt, was preceded by a luncheon of the members at which the President and the Secretary of The Institution were able to be present.

The South Midland Students' Section, despite difficulties arising from the absence on service with His Majesty's Forces of many of its members, are carrying on the Section's activities in a restricted form, two meetings having so far been held.

Western Centre [and the West Wales (Swansea) and the Devon and Cornwall Sub-Centres].

Four meetings of the Centre have up to the present been held, two each at Bristol and Cardiff. At the first of the Bristol meetings the Address of the Chairman, Mr. H. R. Beasant, which will appear in the *Journal* in February, was delivered. It is the intention to continue the monthly meetings throughout the remainder of the session as far as possible, the only change from normal arrangements being the alteration of the time of the Bristol meetings from 6 p.m. to 5 p.m.

The Committee have decided to arrange for a luncheon to be held on the 10th February in Bristol which will take the place of the usual Annual Dinner. It is hoped that it will be possible for the Faraday Lecture by Mr. C. E. Fairburn on "Electric Traction" to be delivered at Bristol in March.

The arrangement of meetings by the Bristol Students' Section has not yet been practicable this session, but endeavours are being made to resume activities, probably with the help of London students of King's College and Faraday House who are now resident in the district.

The West Wales (Swansea) Sub-Centre are maintaining their meetings, held on Saturday afternoons at monthly intervals. At the first of these meetings Mr. T. H. Davies, the Sub-Centre Chairman, delivered his Address, to be published in March in the *Journal.*

In view of the local conditions and the wide distribution of the membership, it has not so far been possible to arrange for any meetings of the Devon and Cornwall Sub-Centre this session.

Hampshire Sub-Centre.

The Sub-Centre Committee have decided that under present conditions the holding of the usual meetings at Portsmouth and Southampton is not advisable. No meetings of the Sub-Centre will therefore take place until further notice.

Northern Ireland Sub-Centre.

A regular programme of meetings is being followed this session, these being held at monthly intervals. The opening meeting took place in October, when the Address of the Chairman, Mr. F. W. Parkinson, was delivered. This Address will appear in the *Journal* in March. At the November and December meetings discussions took place on "Electricity in Agriculture" and "Voltage-operated Earth-leakage Protection" respectively.

Among the arrangements contemplated for the remainder of the session is a Joint Meeting in February with the Belfast Association of Engineers.

E.R.A. REPORT

The Secretary has been asked by the British Electrical and Allied Industries Research Association to draw attention to the following Report which has recently been issued:—

E.R.A. Report Ref. W/T2: A Critical Study of the Application of Electricity to Agriculture and Horticulture (By C. A. Cameron Brown, B.Sc.).

This critical study has been prepared by the Association as a starting point for its researches into the various applications of electricity to agricultural operations.

The subject is introduced by a general section on the issues affecting supply. The various applications are then considered in detail.

The difficulties confronting ploughing and heavy cultivations are outlined; but the conclusion drawn is that, in the event of conditions calling for an active solution of the problem, the technical difficulties could be solved.

Electrical power in barns is dealt with as a comparatively straightforward application which raises few problems calling for research, other than experimental investigation into the improvement of load factor and further elimination of manual labour.

The problems in connection with electrical power in dairy farming are more economic in character. Research is required in order to develop the labour-saving aspects of electrical operation to the full, and also to improve the methods of loading so as to encourage low tariffs. Work already carried out in this direction is described.

Poultry farming introduces such technical complications as the effect of supply failure on eggs and chicks. Work on this subject is quoted and discussed, as well as various experimental investigations of the different ways of applying electrical heat to brooders, etc.

The possibilities of applying electrical power to horticulture and to fruit production are each the subject of main sections of the Report; but perhaps the most interesting applications appear in a section devoted to special applications, which include crop drying, electroculture, beehive heating and electric fences.

The Report, which includes a bibliography containing 234 references, should be of use to electricity supply authorities operating in rural areas, also to manufacturers of farm machinery and to the various agricultural interests involved.

Copies may be obtained from the British Electrical and Allied Industries Research Association, 15 Savoy Street, London, W.C.2, price 2s. (postage 5d.).

BRITISH STANDARDS

The Secretary has been asked by the British Standards Institution to draw attention to the following new and revised specifications, copies of which can be obtained from the British Standards Institution, 28, Victoria Street, London, S.W.1, price 2s. (postage 3d.).

Rubber Mats for Electrical Purposes (B.S. No. 921).

This specification has been issued in order to meet the demand for a Standard Specification for these mats, but it is not intended to imply that rubber mats should afford the sole means of protection when working on electrical circuits.

Wherever possible, further precautions should be taken against the risk of shock and short-circuit. In this connection attention has been drawn to the fact that, in places in which the Home Office Regulations apply, it may be illegal in certain cases for work to be done on live conductors or apparatus at voltages in excess of medium voltage, i.e. 650 volts. For instance, Regulation 18(*d*) implies that work may be carried out only on sections which have been made dead and suitably screened from adjacent live conductors.

The specification covers scope, construction, thickness, weight, workmanship and finish. Electrical, mechanical and ageing tests have also been included.

Impulse-Voltage Testing (B.S. No. 923).

The question of impulse-voltage testing has become of considerable importance in recent years, and a specification dealing with definitions and general principles was issued in 1938 by the International Electrotechnical Commission. This specification has now been issued by the B.S.I. as a British Standard and should prove of considerable interest to all manufacturers and purchasers of electrical plant. The object of impulse-voltage testing is, of course, to determine the effect of voltage surges of short duration on electrical installations and on their individual parts, the surges being such as are caused especially by lightning discharges.

The terminology used in impulse-voltage testing is somewhat peculiar and, unless the meaning of such expressions as the time to half value of the wave-tail is clearly defined, confusion and bewilderment will ensue. Three pages of the specification are therefore devoted to definitions. The remainder of the document deals with the general principles of the generation of impulse voltages, the measurement of wave shapes and the measurement of impulse voltages. The standard wave shape for testing purposes is also prescribed.

Graphic (Recording or Chart-Recording) Ammeters, Voltmeters, Wattmeters, Power-Factor Meters and Frequency Meters (B.S. No. 90).

Progress made in the industry since the 1929 edition of this British Standard has made it desirable to bring the specification up to date and a revision has recently been published.

The new edition includes a graphic voltmeter having a maximum error of 1 per cent, being comparable with that of a first-grade indicating instrument. A graphic frequency meter with a maximum permissible error of 1/10th of a cycle per sec. is also covered, such precision being required now that the mean supply frequency is so closely controlled against time.

Several types of new instruments are included for the first time, e.g. rectifier-operated graphic ammeters and voltmeters and iron-cored electrodynamic graphic wattmeters. Requirements covering the use of synchronous motors for driving and timing the charts have also been laid down.

Domestic Electrical Refrigerators (B.S. No. 922).

This specification, which has recently been issued, is the result of representations made two years ago by a group of engineers interested in the development of the domestic electrical refrigerator; a representative conference unanimously endorsed this request.

The Standard is based largely on the Household Electric Refrigerator Standards prepared by the American National Electrical Manufacturers' Association, the National Test Code for Domestic Refrigerators issued by the Standards Association of Australia, and the provisions of the Canadian Electrical Code issued by the Canadian Engineering Standards Association. It comprises methods of computation of cabinet volume and food-storage surface area, certain constructional details, clauses covering the rating of the motor, requirements for the electric circuits and a section on testing.

PROMOTIONS AND TRANSFERS OF MEMBERS ON SERVICE WITH H.M. FORCES (FIFTH LIST)*

Members

Name	*Corps, etc.*	*Rank*
Lawrie, T.	Royal Naval Volunteer Reserve	Lieutenant

Associate Members

Name	*Corps, etc.*	*Rank*
Adams, R. M.	Indian Signal Corps	Major
Coates, G. H.	Royal Signals	Captain
Cubitt, R. H.	N. Somerset Yeomanry	Sergeant
de Nordwall, C. H.	Royal Engineers	Sec. Lieut.
Edgecombe, P. J. E.	Royal Engineers	Major
Follenfant, J. L.	Royal Engineers	Sec. Lieut.
Graham, A.	Royal Engineers	Captain
Graham, A. G.	Royal Air Force (V.R.)	Pilot Officer
Gunton, R.	Royal Naval Volunteer Reserve	Lieutenant
Heath, F. J. R.	Royal Engineers	Major
Henry, H. G.	Royal Army Ordnance Corps	Captain
Instrall, R. C.	Royal Signals	Lieut.-Col.
Jackson, G. E.	Royal Army Ordnance Corps	Captain
Jarvis, J. R.	Royal Navy	Commander
Johnstone-Hall, F. C.	Royal Army Ordnance Corps	Lieut.-Col.
Jordan, R. J.	Royal Signals	Captain
McCleery, D. K.	Royal Navy	Inst. Lieut.-Comdr.
Maddison, W. H.	Royal Artillery	Lieutenant
Milway, J. T.	Royal Army Ordnance Corps	Captain
Neal, H.	Royal Army Ordnance Corps	Captain
Norfolk, L. W.	Royal Engineers	Captain
Pulham, G. B.	Royal Naval Volunteer Reserve	Lieutenant
Roberts, L. C.	Royal Engineers	Sec. Lieut.
Sanders, K. L.	Royal Signals	Captain
Smith, A. G.	Royal Signals	Captain
Tyack, F. G.	Royal Artillery	Captain
Wainscot, F. S.	Royal Air Force	Squadron Leader
Walker, A. W. P.	Royal Army Ordnance Corps	Captain
Wheatley, M. S.	Royal Signals	Lieut.-Col.
Whitmore, G.	Royal Engineers	Major

* See *Journal I.E.E.*, 86, pp. 311 and 510; and 87, pp. 110 and 356.

Associates

Name	*Corps, etc.*	*Rank*
Angell, F.	Royal Army Ordnance Corps	Captain
Reed, A. W.	Royal Army Ordnance Corps	Major
Rowan, A. W.	Royal Naval Volunteer Reserve	Lieutenant
Smith, N. A.	Royal Artillery	Captain

Graduates

Name	*Corps, etc.*	*Rank*
Adams, E. F.	Royal Engineers	Lieutenant
Anstey, F. B.	Royal Engineers	Sec. Lieut.
Apps, A. F.	Royal Naval Volunteer Reserve	Sub-Lieut.
Bawtree, H. M.	Royal Signals	Sec. Lieut.
Birchenhough, H.	Royal Army Ordnance Corps	Captain
Brecknell, W. A.	Royal Engineers	Staff Sergeant
Castellan, G. E.	Royal Engineers	Company Quartermaster Sergt.
Collop, A. D.	Royal Naval Volunteer Reserve	Lieutenant
Crawshaw, G.	Officer Cadet Training Unit	Cadet
Crow, D. R.	Royal Signals	Sec. Lieut.
Drayton, C. R.	Royal Engineers	Lance-Corporal
Earl, V. G.	Royal Naval Volunteer Reserve	Lieutenant
Fielding, T. J.	Royal Signals	Captain
Hawker-Smith, R. E.	Royal Air Force	Leading Aircraftman
Hawkins, H. J.	Royal Naval Volunteer Reserve	Lieutenant
Higson, H. W.	Royal Signals	Sec. Lieut.
Holbrook, G. W.	Royal Signals	Sec. Lieut.
Hohn, J. G.	Royal Naval Volunteer Reserve	Lieutenant
Howe, R. L.	Officer Cadet Training Unit	Cadet
Logan, T. B.	Royal Naval Volunteer Reserve	Lieutenant
Nepean, E. Y.	Royal Signals	Major
Parsons, J. W.	Royal Naval Volunteer Reserve	Lieutenant
Richardson, R. F.	Royal Engineers	Sec. Lieut.
Romans, G. O.	East Yorks Regiment	Lance-Corporal
Smith, C. C.	Royal Engineers	Sec. Lieut.
Swinney, E.	Royal Air Force	Flt. Lieut.
Taylor, H. S.	Royal Naval Volunteer Reserve	Lieutenant
Wilson, T. C.	Officer Cadet Training Unit	Cadet

Students

Name	*Corps, etc.*	*Rank*
Brown, F. L.	Royal Artillery	Gunner
Busby, J. D. A.	Officer Cadet Training Unit	Cadet
Davy, A. G. J.	King's Shropshire Light Infantry	Sec. Lieut.
Edwards, E. T. A.	Royal Engineers	Corporal
Hadland, P.	Royal Signals	Sec. Lieut.
Karamelli, A. H.	Royal Signals	Sec. Lieut.
Laidler, W. R.	Royal Artillery	Bombardier
Longman, P. H.	Royal Signals	Sec. Lieut.
Powell, E. B.	Royal Air Force	Sergeant

Name	*Corps, etc.*	*Rank*
Roberson, R. S.	Royal Signals	Sec. Lieut.
Solomon, T. M.	Royal Artillery	Sergeant
Sykes, W. H.	Royal Air Force	Leading Aircraftman
Wilcox, A.	Royal Naval Volunteer Reserve	Lieutenant

MEMBERS ON SERVICE WITH H.M. FORCES (CORRECTION TO SIXTH LIST*)

The name of the following Member was inadvertently included in the above List on page 354 of the September (1940) issue of the *Journal* and should be deleted:—

Name	*Corps, etc.*	*Rank*
Calverley, J. E.	Royal Engineers	Sec. Lieut.

LOCAL CENTRE COMMITTEES ABROAD

The present constitution of the Local Centre Committees abroad is as follows:—

Argentine

M. F. Ryan, C.B.E. (*Chairman*).
R. Wright (*Vice-Chairman*).

E. Berry. H. J. McPhail.
C. T. T. Comber. G. W. Munday.
K. N. Eckhard. J. D. Smith.

R. G. Parrott (*Hon. Secretary*).

China

J. Haynes Wilson, M.C. (*Chairman*).
A. B. Raworth (*Vice-Chairman*).

R. L. Evans. W. Miles.
S. Flemons. W. L. E. Miller.
A. H. Harvey. S. Stucken, B.A.
C. H. Mellor. W. H. Wei, M.Sc.(Eng.).

J. A. McKinney (*Hon. Secretary*).

OVERSEAS COMMITTEES

The present constitution of the Overseas Committees is as follows:—

Australia

NEW SOUTH WALES.

R. V. Hall, B.E. (*Chairman*).

V. J. F. Brain, B.E. W. J. McCallion, M.C.
L. F. Burgess, M.C. V. L. Molloy.
W. R. Caithness. A. S. Plowman.
E. F. Campbell, B.Eng.

C. A. Saxby (*Hon. Secretary*).

QUEENSLAND.

J. S. Just (*Chairman and Hon. Secretary*).

W. Arundell. F. R. L'Estrange.
A. Boyd, D.Sc. L. G. Pardoe, B.Eng.
E. B. Freeman, B.Eng.

SOUTH AUSTRALIA.

F. W. H. Wheadon (*Chairman and Hon. Secretary*).

J. R. Brookman, M.E. Sir W. G. T. Goodman.
E. V. Clark. W. Inglis.
J. S. Fitzmaurice. J. C. Stobie, B.E.

VICTORIA AND TASMANIA.

H. R. Harper (*Chairman and Hon. Secretary*).

J. M. Crawford. T. P. Strickland.
H. C. Newton. R. J. Strike.
S. H. Witt.

WESTERN AUSTRALIA.

J. R. W. Gardam (*Chairman*).

F. C. Edmondson. S. Johnson.
Prof. P. H. Fraenkel, B.E. W. H. Taylor.

A. E. Lambert, B.E. (*Hon. Secretary*).

Ceylon

Major C. H. Brazel, M.C. (*Chairman*).

H. Fenton-Jones. S. Rajanayagam.
C. H. Jones. L. W. G. Starbuck.
D. Lusk. E. H. Targett.
G. E. Misso. G. R. Wiltshire.
R. H. Paul, M.A., B.Sc.

D. P. Bennett (*Hon. Secretary*).

India

BOMBAY.

R. G. Higham (*Chairman*).

S. J. W. Baldwin. N. R. Khambati.
C. M. Cock. E. G. Lazarus.
K. M. Dordi. G. L. Rhodes, M.A.

A. L. Guilford, B.Sc.Tech. (*Hon. Secretary*).

CALCUTTA.

S. W. Redclift (*Chairman*).

K. N. Arnold. E. B. C. Preston.
N. C. Bhattacharji. H. G. Sale.
J. Parkinson. Prof. F. W. Sharpley, F.R.S.E.

D. H. P. Henderson (*Hon. Secretary*).

LAHORE.

V. F. Critchley (*Chairman*).

J. C. Brown. P. N. Mukerji, M.Sc.
M. A. Haque. T. S. Rao, B.E.
S. S. Kumar, M.Sc.(Eng.). N. Thornton.
Prof. T. H. Matthewman.

S. Singh, M.Sc. (*Hon. Secretary*).

MADRAS.

Major E. G. Bowers, M.C. (*Chairman*).

K. Aston, M.Sc. C. E. Preston.
C. V. K. Chetty, M.B.E., B.A., B.Sc.Tech. J. J. Rudra, M.A., Ph.D., B.Sc.
P. Govindakrishnayya. R. M. Steele.
E. J. B. Greenwood. K. J. Thouless.
Prof. T. H. Matthewman. R. Wright.
T. J. Mirchandani, M.Sc.(Eng.). G. Yoganandam, B.E.

W. Le C. de Bruyn (*Hon. Secretary*).

New Zealand

F. T. M. Kissel, B.Sc. (*Chairman*).

R. H. Bartley. E. Hitchcock.
M. C. Henderson.

J. McDermott (*Hon. Secretary*).

South Africa

TRANSVAAL.

W. Elsdon-Dew (*Chairman and Hon. Secretary*).

J. B. Bullock. Prof. O. R. Randall, Ph.D., M.Sc.
S. E. T. Ewing. A. Rodwell.
V. Pickles. L. B. Woodworth.
B. Price.

COMMITTEES, 1940–41*

Meter and Instrument Section Committee

Chairman: C. W. Marshall, B.Sc.
Vice-Chairman: W. Phillips.
Immediate Past-Chairman: F. E. J. Ockenden.

A. H. M. Arnold, D.Eng., Ph.D. D. C. Gall.
A. T. Dover. L. B. S. Golds.
C. W. Hughes, B.Sc.

* See *Journal I.E.E.*, 87, p. 353.

* The President is, *ex-officio*, a member of all Committees of The Institution.

Meter and Instrument Section Committee—*continued.*

A. E. Jepson.
F. J. Lane, M.Sc.
E. H. Miller.
E. W. Moss.
A. G. O'Neill.
W. G. Radley, Ph.D.(Eng.).
S. H. Richards.

And

A representative of the Council.
The Chairman of the Papers Committee.

Transmission Section Committee

Chairman: H. J. Allcock, M.Sc.
Vice-Chairman: S. W. Melsom.
Immediate Past-Chairman: F. W. Purse.

W. M. Booker.
W. Fennell.
R. E. G. Horley.
J. W. Leach.
J. A. Lee.
W. H. Lythgoe.
E. T. Norris.
J. S. Pickles, B.Sc.Tech.
T. R. Scott, B.Sc.
F. H. Sharpe, B.Sc.
J. A. Sumner.
H. Willott Taylor.

A representative of the Council.
The Chairman of the Papers Committee.
The following representatives of Government Departments:—
Central Electricity Board: C. W. Marshall, B.Sc.
Electricity Commission: H. W. Grimmitt.
Post Office: P. B. Frost, B.Sc.(Eng.).

Wireless Section Committee

Chairman: W. J. Picken.
Vice-Chairman: T. E. Goldup.
Immediate Past-Chairman: E. B. Moullin, M.A., Sc.D.

C. W. Cosgrove, B.Sc.(Eng.).
A. J. A. Gracie, B.Sc.
L. W. Hayes.
T. H. Kinman.
G. S. C. Lucas.
J. S. McPetrie, D.Sc., Ph.D.
W. L. McPherson, B.Sc.(Eng.).
Col. G. D. Ozanne, M.C.
R. P. Ross, B.Sc.(Eng.).
M. G. Scroggie, B.Sc.
R. L. Smith-Rose, D.Sc., Ph.D.
R. T. B. Wynn, M.A.

And

A representative of the Council.
The Chairman of the Papers Committee.
The following representatives of Government Departments:—
Admiralty: Capt. P. F. Glover, R.N.
Air Ministry and Ministry of Aircraft Production: N. F. S. Hecht.
Post Office: A. H. Mumford, B.Sc.(Eng.).
War Office: Col. R. Elsdale, O.B.E., M.C., M.A.

Among the committees appointed by the Council for 1940–41 are the following:—

Home Security Advisory Committee

S. B. Donkin.
P. Good.
H. W. Swann.
H. T. Young.

Benevolent Fund Committee

The President (*Chairman*).

The Rt. Hon. The Viscount Falmouth; F. Gill, O.B.E.; Prof. R. O. Kapp, B.Sc.; Sir George Lee, O.B.E., M.C.; C. W. Marshall, B.Sc.; A. P. Young, O.B.E.	Representing the Council.
J. R. Cowie; J. H. Johnson; H. Marryat	Representing the Contributors.

And the Chairman of each Local Centre in Great Britain and Ireland.

Informal Meetings Committee

H. Brierley.
H. J. W. Bullard.
G. Davidson.
G. H. Fowler.
W. A. Ritchie.
F. Jervis Smith.
D. A. Stewart.
H. G. Taylor, D.Sc.(Eng.).
F. L. Veale.

A representative of the General Purposes Committee.
The Chairman of the Papers Committee.
The Chairman of the London Students' Section.

Model General Conditions Committee

P. V. Hunter, C.B.E.
F. Lydall.
A. E. Tanner.

And

E. G. Batt; C. Proctor Banham; V. Watlington, M.B.E.; The Hon. J. R. Rea	British Electrical and Allied Manufacturers' Association.
H. A. F. Bennett; H. C. C. Budd	Cable Makers' Association.
J. A. Lee	Central Electricity Board.
J. C. Dalton	Incorporated Association of Electric Power Companies.
R. Birt; A. Nichols Moore	Incorporated Municipal Electrical Association.
P. L. Rivière	London Electricity Supply Association.
G. W. Spencer Hawes, O.B.E.	Provincial Electric Supply Association.

Operating Theatres Electrical Apparatus Committee

Forbes Jackson
E. H. Rayner, M.A., Sc.D.
H. W. Swann.
Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng.
Prof. D. T. A. Townend, D.Sc., Ph.D.
H. T. Young.

And	*Representing*
Lionel Colledge, F.R.C.S.	British Medical Association.
R. W. L. Phillips	I.E.E. Wiring Regulations Committee.
P. G. Phelps; E. H. Willis	Manufacturers of electro-medical apparatus.
H. S. Souttar, C.B.E.	Royal College of Surgeons.
Dr. C. F. Hadfield, M.B.E., M.A.	Royal Society of Medicine.

Local Centres Committee

W. Fennell.
P. Good.
H. C. Lamb.
Sir George Lee, O.B.E., M.C.
A. L. Lunn.
Col. Sir Thomas F. Purves, O.B.E.
H. T. Young.

And the Chairman of each Local Centre and Sub-Centre.

Overseas Activities Committee

Lieut.-Col. K. Edgcumbe, T.D.
A. P. M. Fleming, C.B.E., D.Eng., M.Sc.
F. Gill, O.B.E.
W. G. Hendrey.
F. Lydall.
C. R. Webb.
Johnstone Wright.

And

The Chairman of the Finance Committee.
The Chairman of the General Purposes Committee.
The Chairman of the Membership Committee.
The Chairman of the Papers Committee.

Also the following co-opted members:—

J. W. Bell.
Prof. J. K. Catterson-Smith, M.Eng.
W. P. Gauvain.
A. C. Kelly.
J. T. Mertens.
E. A. Mills.
H. Nimmo.
E. E. Sharp.
V. Watlington, M.B.E.

Scholarships Committee

Prof. J. K. Catterson-Smith, M.Eng.
J. M. Donaldson, M.C.
Prof. W. J. John, B.Sc.(Eng.).
Prof. R. O. Kapp, B.Sc.
Prof. E. W. Marchant, D.Sc.
H. Marryat.

"Science Abstracts" Committee

L. G. Brazier, Ph.D., B.Sc.
P. Good.
Prof. E. W. Marchant, D.Sc.
C. C. Paterson, O.B.E., D.Sc.

And	*Representing*
J. H. Awbery, B.A., B.Sc.; Prof. A. Ferguson, M.A., D.Sc.; D. Owen, B.A., D.Sc.; W. Jevons, D.Sc., Ph.D.	Physical Society.
R. H. Fowler, O.B.E., M.A.	Royal Society.

Ship Electrical Equipment Committee

A. G. S. Barnard.
Major B. Binyon, O.B.E., M.A.
J. H. Collie.
P. Dunsheath, O.B.E., M.A., D.Sc.
S. Harcombe, M.A., B.Sc.
A. Henderson.
J. F. W. Hooper.
P. V. Hunter, C.B.E.
F. Johnston.
J. W. Kempster.
A. Cecil Livesey.
S. W. Melsom.
N. W. Prangnell.
Col. A. P. Pyne, R.A. (T.)(Ret.).
C. Rodgers, O.B.E., B.Sc., B.Eng.
F. A. Ross.
T. A. Sedgwick.
H. D. Wight.
H. A. Wilson.

And	*Representing*
J. S. Pringle, O.B.E.	Admiralty.
H. Cranwell; W. T. Williams, O.B.E.	Board of Trade.
B. Hodgson; J. Turnbull	British Corporation Register of Shipping and Aircraft.
T. Ratcliffe, M.Sc.Tech.; C. W. Saunders	British Electrical and Allied Manufacturers' Association.
E. W. Andrews	Electrical Contractors' Association
S. A. Smith, M.Sc.; N. H. Swancoat	Institute of Marine Engineers.
J. F. Nielson	Institution of Engineers and Shipbuilders in Scotland.
W. J. Belsey	Institution of Naval Architects.
S. F. Dorey, D.Sc.; G. O. Watson	Lloyd's Register of Shipping.
W. S. Wilson	North-East Coast Institution of Engineers and Shipbuilders.
(To be nominated)	Electrical Contractors' Association of Scotland.

Wiring Regulations (Nucleus) Committee

H. J. Cash.
P. Dunsheath, O.B.E., M.A., D.Sc.
W. Fennell.
E. B. Hunter.
P. V. Hunter, C.B.E.
H. Marryat.
R. W. L. Phillips.
F. W. Purse.
E. Ridley, M.B.E.
C. Rodgers, O.B.E., B.Sc., B.Eng.
J. F. Stanley, B.Sc.(Eng.).

REPRESENTATIVES OF THE INSTITUTION ON OTHER BODIES

The following is a list of representatives of The Institution on other bodies, and gives the dates on which they were appointed:—

Bristol University:
H. F. Proctor (8 Jan., 1925).

British Cast Iron Research Association:
E. B. Wedmore, C.B.E. (25 Sept., 1924).

British Electrical and Allied Industries Research Association:

Council:
J. M. Donaldson, M.C. (18 Dec., 1930).
P. V. Hunter, C.B.E. (16 Nov., 1939).

Sectional Committee on Unclassified Researches:
A. H. Railing, D.Eng. (8 Jan., 1931).

Sub-Committee on Connections to Large Gas-filled Lamps:
C. C. Paterson, O.B.E., D.Sc. (24 Oct., 1929).
B. Welbourn (24 Oct., 1929).

Sub-Committee on Earthing and Earth Plates:
S. W. Melsom (31 Jan., 1930).

British Electrical Development Association: Committee on Rural and Agricultural Electrification:
J. M. Donaldson, M.C. (20 Oct., 1927).
R. Grierson (20 Oct., 1927).

British School for International Bibliography:
L. G. Brazier, Ph.D., B.Sc. (14 Nov., 1940).

British Society for International Bibliography:
L. G. Brazier, Ph.D., B.Sc. (14 Nov., 1940).

British Standards Institution:

Engineering Divisional Council:
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (28 March, 1940.)
C. C. Paterson, O.B.E., D.Sc. (10 March, 1938).
Col. Sir Thomas F. Purves, O.B.E. (27 April, 1939).

Electrical Industry Committee:
J. R. Beard, M.Sc. (27 June, 1940).
W. K. Brasher, B.A. (27 June, 1940).
Lt.-Col. K. Edgcumbe, T.D. (5 March, 1940).
F. Gill, O.B.E. (21 May, 1914).
J. S. Highfield (21 May, 1914).
P. V. Hunter, C.B.E. (27 June, 1940).

Technical Committee on Electric Power Cables:
E. B. Hunter (20 Oct., 1938).
Col. A. P. Pyne, R.A. (T.)(Ret.), (3 Nov., 1938).
G. O. Watson (20 Oct., 1938).
H. D. Wight (20 Oct., 1938).

Technical Committee on Electric Clocks:
E. B. Hunter (5 Dec., 1935).

Technical Committee on Electric Signs:
L. Barlow (14 May, 1931).
R. W. L. Phillips (17 Feb., 1932).

Technical Committee on Electrical Accessories:
H. J. Cash (31 March, 1925).
F. W. Purse (31 March, 1925).

Technical Committee on Electrical Instruments:
Lt.-Col. K. Edgcumbe, T.D. (15 Feb., 1923).

Technical Committee on Electrical Nomenclature and Symbols:
C. C. Paterson, O.B.E., D.Sc. (8 Jan., 1920).

Technical Committee on Electricity Meters:
A. J. Gibbons, B.Sc.Tech. (28 March, 1930).
O. Howarth (22 Oct., 1936).
G. F. Shotter (28 Feb., 1929).

Technical Committee on Identification of Pipe-lines in Buildings:
R. Grierson (11 May, 1933).

Technical Committee on Lifts, Hoists, and Escalators:
H. Marryat (25 Oct., 1934).

Technical Committee on Overhead Transmission Lines Material:
J. L. Eve (11 Nov., 1936).

Technical Committee on Provision in Buildings for Ducts for Service Pipes:
H. J. Cash (1 Dec., 1938).
E. B. Hunter (1 Dec., 1938).

Technical Committee on Regulations for Overhead Lines:
W. Fennell (23 April, 1936).
S. R. Siviour (23 April, 1936).

Technical Committee on Safety Requirements:
H. J. Cash (22 Oct., 1936).
R. W. L. Phillips (22 Oct., 1936).
E. Ridley, M.B.E. (11 Feb., 1937).

Technical Committee on Testing and Expressing the Overall Performance of Radio Receivers:
R. P. G. Denman, M.A. (21 Oct., 1937).

Technical Committee on Under-floor Duct Systems:
H. J. Cash (11 Nov., 1938).
E. B. Hunter (22 Oct., 1936).

Sub-Committee on Automatic Change-over Switches for Emergency Lighting Systems:
E. Ridley, M.B.E. (22 Oct., 1936).

Sub-Committee on Cables for Use on Board Ship:
A. Henderson (18 May, 1939).
E. B. Hunter (20 Oct., 1938).
Col. A. P. Pyne, R.A. (T.)(Ret.), (3 Nov., 1938).
G. O. Watson (20 Oct., 1938).
H. D. Wight (20 Oct., 1938).

Sub-Committee on Ceiling Roses:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).

Sub-Committee on Conduit Fittings:
H. J. Cash (18 May, 1927).

British Standards Institution—*continued.*

Sub-Committee on Connectors for Portable Appliances:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).
J. W. J. Townley (11 May, 1937).

Sub-Committee on Connectors for Radio Apparatus:
R. W. L. Phillips (6 Jan., 1931).

Sub-Committee on Copper Conduit Tubes (Light Gauge):
H. Marryat (17 Dec., 1936).

Sub-Committee on Cut-outs for Radio Receivers:
S. W. Melsom (5 Dec., 1935).

Sub-Committee on Distribution Boards:
E. B. Hunter (25 Feb., 1927).
S. W. Melsom (25 Feb., 1927).

Sub-Committee on Fuses:
H. J. Cash (22 June, 1926).
E. B. Hunter (25 Feb., 1927).
S. W. Melsom (25 Feb., 1927).
G. O. Watson (23 Feb., 1939).

Sub-Committee on Instrument Transformers:
G. F. Shotter (22 Feb., 1934).

Sub-Committee on Lead Alloys for Cable Sheathing:
B. Welbourn (22 June, 1933).

Sub-Committee on Letter Symbols:
A. T. Dover (21 Nov., 1929).

Sub-Committee on Low-voltage Transformers for Lighting Equipment and Bell-ringing Circuits:
G. F. A. Norman (11 Feb., 1937).

Sub-Committee on Mains Supply Apparatus for Radio Receivers, etc.:
R. W. L. Phillips (11 Dec., 1930).
F. W. Purse (16 Oct., 1928).

Sub-Committee on Non-ignitable and Self-extinguishing Boards for Electrical Purposes:
S. W. Melsom (24 Oct., 1935).
E. Ridley, M.B.E. (24 Oct., 1935).

Sub-Committee on Porcelain Insulators for Overhead Lines:
P. K. Davis (11 May, 1939).
H. Willott Taylor (11 May, 1939).

Sub-Committee on Protected-type Plugs and Sockets:
H. J. Cash (26 Oct., 1932).
F. W. Purse (26 Oct., 1932).
J. W. J. Townley (11 Mar., 1937).

Sub-Committee on Radio Interference from Trolleybuses and Tramcars:
C. C. Paterson, O.B.E., D.Sc. (7 Nov., 1935).
H. Wallis (7 Nov., 1935).

Sub-Committee on Radio Nomenclature and Symbols:
Col. A. S. Angwin, D.S.O., M.C., B.Sc.(Eng.) (7 April, 1932).

Sub-Committee on Telephone and Radio Connectors:
R. W. L. Phillips (28 Feb., 1935).
A. J. L. Whittenham (28 Feb., 1935).

Sub-Committee on Tumbler Switches:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).

Sub-Committee on Wall-plugs and Sockets:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).
J. W. J. Townley (11 Mar., 1937).

Sub-Committee on Welding Plant and Equipment:
Major J. Caldwell, J.P. (26 Oct., 1933).

Panel on Graphical Symbols for Interior Installations:
G. F. A. Norman (11 Feb., 1937).
E. Ridley, M.B.E. (11 Feb., 1937).

Colliery Requisites Industry Committee:
C. T. Allan (3 July, 1924).

Technical Committee on Mining Electrical Plant:
A. C. Sparks (27 March, 1930).

British Standards Institution—*continued.*

Birmingham Regional Committee:
F. C. Hall.

Glasgow Regional Committee:
F. Anslow.

Manchester Regional Committee:
W. T. Anderson.

Newcastle Regional Committee:
S. A. Simon, B.A.

Sheffield Regional Committee:
M. Wadeson.

Technical Committee for Co-ordinating the Work on Units and Quantities of the Building, Chemical, and Engineering Divisional Councils:
E. B. Wedmore, C.B.E. (3 Feb., 1938).

Technical Committee for the Standardization of Clamps for connecting Earthing Wires to Metal Water Pipes:
F. W. Purse (16 Nov., 1939).

Technical Committee on Coal:
W. M. Selvey (19 Jan., 1928).

Technical Committee on Engine Testing Fittings:
W. M. Selvey (22 Oct., 1931).

Technical Committee on Engineering Symbols and Abbreviations:
A. T. Dover (21 Nov., 1929).

Technical Committee on Fans:
Prof. R. O. Kapp, B.Sc. (22 Oct., 1931).

Technical Committee on Land Boilers:
W. M. Selvey (7 April, 1932).

Technical Committee on Larch Poles:
B. Welbourn (21 Jan., 1932).

Technical Committee on Lightning Conductors:
Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng. (30 Jan., 1936).

Technical Committee on Measurement of Temperature, Flow and Pressure of Fuel and Flue Gases:
G. A. Whipple, M.A. (28 April, 1938).

Technical Committee on Methods of Test for Dust Extraction Plant:
C. L. Blackburn, B.A. (25 Oct., 1934).

Technical Committee on Pipe Flanges:
W. M. Selvey (14 April, 1921).

Technical Committee on Pump Tests:
R. S. Allen (2 July, 1931).

Technical Committee on Railway Signalling Apparatus:
A. F. Bound (24 Oct., 1929).

Technical Committee on Rating of Rivers:
G. K. Paton (20 Oct., 1927).

Technical Committee on Rubber Belting:
C. Rodgers, O.B.E., B.Sc., B.Eng. (5 Jan., 1928).

Technical Committee on Standardization of Letter Symbols:
L. G. Brazier, Ph.D., B.Sc. (4 July, 1939).

Technical Committee on Traction Poles:
T. L. Horn (4 Feb., 1926).

Sub-Committee on Accessories for Land Boilers:
W. M. Selvey (7 April, 1932).

Sub-Committee on Boiler and Superheater Tubes:
W. M. Selvey (7 April, 1932).

Sub-Committee on Fittings for Land Boilers:
W. M. Selvey (7 April, 1932).

Sub-Committee on Water-Tube Boilers:
W. M. Selvey (7 April, 1932).

Illumination Industry Committee:
Lt.-Col. K. Edgcumbe, T.D. (28 Feb., 1924).
P. Good (28 Feb., 1924).
Prof. J. T. MacGregor-Morris (28 Feb., 1924).
J. W. J. Townley (16 May, 1935).

Welding Industry Committee:
T. Carter (2 Feb., 1939).

Building Industry, National Council for:

Advisory Committee on Building Acts and Bye-Laws:
F. W. Purse (20 Oct., 1932).
H. T. Young (20 Oct., 1932).

Magnesite Composition Flooring Panel:
F. W. Purse (21 Oct., 1937).

Lifts and Escalators Installation Panel:
L. S. Atkinson (30 Mar., 1939).

Central Register of National Service:

General Engineering Committee:
J. R. Beard, M.Sc. (23 Feb., 1939).
W. K. Brasher, B.A. (13 Oct., 1939).
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (15 Dec., 1938).
C. W. Marshall, B.Sc. (14 Nov., 1940).
H. T. Young (23 Feb., 1939).

City and Guilds of London Institute:

Advisory Committee on Electrical Engineering Practice:
Prof. E. W. Marchant, D.Sc. (22 June, 1933).

Advisory Committee on Electrical Installation Work:
Prof. S. Parker Smith, D.Sc. (20 Oct., 1927).

Advisory Committee on Illuminating Engineering Examinations:
C. C. Paterson, O.B.E., D.Sc. (8 April, 1937).

Advisory Committee on Machine Design:
F. H. Clough, C.B.E. (2 Feb., 1939).

Advisory Committee on Telecommunications:
E. H. Shaughnessy, O.B.E. (22 Oct., 1931).

Fellowship Committee:
W. H. Eccles, D.Sc., F.R.S. (19 April, 1928).

Council for the Preservation of Rural England:
J. M. Kennedy, O.B.E. (10 Jan., 1929).

Electrical Association for Women:

Council:
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (18 Dec., 1924).

Committee for Training of Women Demonstrators:
J. R. Beard, M.Sc. (4 Nov., 1937).

Engineering Joint Council:
The President (*ex-officio*).
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (8 Feb., 1940).
H. T. Young (24 Feb., 1938).

Engineering Joint Examination Board:
Prof. C. L. Fortescue, O.B.E., M.A. (24 Mar., 1938).
Prof. R. O. Kapp, B.Sc. (3 Nov., 1938).

Engineering Public Relations Committee:
J. M. Kennedy, O.B.E. (6 May, 1937).

Registration of Engineers Sub-Committee:
J. M. Kennedy, O.B.E. (20 Oct., 1938).

Sub-Committee for Scotland:
Major H. Bell, O.B.E., T.D. (23 May, 1938).

H.T. Conference, Paris: British National Committee:
F. H. Clough, C.B.E. (10 Mar., 1938).
A. H. Railing, D.Eng. (10 Mar., 1938).

Imperial College of Science and Technology: Governing Body:
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (20 Oct., 1938).

Imperial Minerals Resources Bureau Conference: Copper Committee:
B. Welbourn (18 Sept., 1919).

Institute of Industrial Administration: Examinations Advisory Council:
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (25 Oct., 1934).

Institute of Metals: Corrosion Research Committee:
W. M. Selvey (19 July, 1923).

Institution of Civil Engineers:

Earthing to Water Mains Sub-Committee:
P. Dunsheath, O.B.E., M.A., D.Sc. (20 Feb., 1936).
F. W. Purse (20 Feb., 1936).
P. J. Ridd (20 Feb., 1936).

Engineering Precautions (Air Raid) Committee Panel:
S. B. Donkin (11 May, 1939).

International Association for Testing Materials:
J. M. Kennedy, O.B.E. (5 July, 1928).

International Illumination Commission: British National Committee:
Lt.-Col. K. Edgcumbe, T.D. (27 Nov., 1913).
P. Good (18 Sept., 1919).
Prof. J. T. MacGregor-Morris (27 Nov., 1913).
C. C. Paterson, O.B.E., D.Sc. (28 Mar., 1940).
J. W. J. Townley (16 May, 1935).

Joint Committee for National Certificates and Diplomas in Electrical Engineering (England and Wales):
E. S. Byng (16 Nov., 1939).
Prof. C. L. Fortescue, O.B.E., M.A. (4 Nov., 1937).
Prof. Willis Jackson, D.Sc., D.Phil. (14 Nov., 1940).

Joint Committee for National Certificates and Diplomas in Electrical Engineering (Scotland):
Prof. G. W. O. Howe, D.Sc. (10 Jan., 1929).
D. S. Munro (8 Nov., 1934).
R. Robertson, D.L., B.Sc., LL.D. (10 Jan., 1929).
Prof. S. Parker Smith, D.Sc. (10 Jan., 1929).

Joint Committee of the British Electrical and Allied Industries Research Association and The Institution of Civil Engineers, for Research on Earthing to Water Mains:
C. W. Marshall, B.Sc. (24 Feb., 1938).
F. W. Purse (3 Feb., 1938).
W. G. Radley, Ph.D.(Eng.) (3 Feb., 1938).

Joint Committee on Engineering Co-operation Overseas:
F. Gill, O.B.E. (28 April, 1938).

Joint Committee on Materials and their Testing:
S. W. Melsom (16 July, 1938).

Manchester Regional Advisory Council for Technical and other Forms of Further Education: Post Advanced Education Sub-Committee:
L. H. A. Carr, M.Sc.Tech. (20 Jan., 1938).
Prof. Willis Jackson, D.Sc., D.Phil. (11 May, 1939).
J. W. Thomas, LL.B., B.Sc.Tech. (20 Jan., 1938).

Metalliferous Mining (Cornwall) School: Governing Body:
C. C. Hodges (5 Dec., 1940).

National Physical Laboratory: General Board:
J. M. Donaldson, M.C. (7 Nov., 1935).
P. Dunsheath, O.B.E., M.A., D.Sc. (3 Nov., 1938).

National Register of Electrical Installation Contractors:
H. J. Cash (12 March, 1931).
P. V. Hunter, C.B.E. (18 Feb., 1926).
W. R. Rawlings (18 Feb., 1926).
W. M. Selvey (18 Feb., 1926).

National Smoke Abatement Society:
H. C. Lamb (26 Oct., 1933).
C. D. Taite (26 Oct., 1933).

Professional Classes Aid Council:
W. K. Brasher, B.A. (7 Dec., 1939).

Royal Institute of British Architects: Advisory Committee to Re-draft Home Office Handbook No. 5 on Structural Precautions:
H. T. Young (5 Oct., 1939).

Royal Society:

National Committee on Physics:
Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng. (19 Nov., 1936).

National Committee for Scientific Radio:
Prof. C. L. Fortescue, O.B.E., M.A. (19 Nov., 1936).
Sir George Lee, O.B.E., M.C. (5 Oct., 1939).

Science Museum, South Kensington: Advisory Council:
C. C. Paterson, O.B.E., D.Sc. (1 July, 1937).

Town Planning Institute: Committee on Overhead Transmission Lines:
J. M. Kennedy, O.B.E. (7 April, 1932).

Union of Lancashire and Cheshire Institutes (Panel for Engineering):
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (28 Feb., 1924).
Prof. Miles Walker, M.A., D.Sc., F.R.S. (28 Feb., 1924).

University College, Nottingham: Electrical Engineering Advisory Committee:
A. D. Phillips (23 Feb., 1933).

War Office Mechanization Board:
W. H. Eccles, D.Sc., F.R.S. (19 Jan., 1928).

Women's Engineering Society:
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (25 Sept., 1924).

World Power Conference (British National Committee):
Sir Archibald Page (28 April, 1938).

ELECTIONS AND TRANSFERS

At the Ordinary Meeting of The Institution held on the 14th November, 1940, the following elections and transfers were effected:—

Elections

Associate Members

Alston, Geoffrey Kirkham, B.Sc.(Eng.).
Baird, John Douglas, B.Sc. Tech.
Baldwin, Harold Townley, B.Eng.
Balmain, George Harcourt S., Capt.
Bates, Herbert Owen, Lieut., R.A.O.C.
Beaumont, Eric Basil M.
Buchanan, William Hudspilt, B.A.
Cafferata, Harold.
Clark, John Bradshaw.
Clarke, George Green.
Clarkson, George William.
Cowan, James.
Dennis, Leslie Arthur.
Dent, Arthur George H.
Edwards, Wodehouse Samuel.
Flint, James George.
Gill, Cyril James.
Gosney, George.
Herring, Horace Raphael.
Howard, Percy.
Huartson, Harold.
Jenkins, George Hollings.
Kaufmann, Max.
Lambert, James Edwin.
MacFarlane, Daniel D., B.Sc. (Eng.).
Miller, Ronald George, Capt., R. Signals.
Muscutt, John, B.Sc.(Eng.).
Parkington, John Roger.
Patel, Jashbhai Chhotabhai, B.Sc.
Purslow, William Bruce.
Roche, William Henry, B.E.
Rogers, Frank Alexander.
Samson, George Albert.
Smart, Robert Masson.
Story, Albert Leonard, M.Sc.(Eng.).
Sutton, Cyril John.
Turner, Charles Robert.
Twycross, Albert Edward.
Tyrrell, Arthur James.
Weigall, Denny Brome, B.A.
Wheeler, Leonard Keith, B.Sc.(Eng.).
Wild, Robert William.

Associates

Adorjan, Paul.
Baigent, Horace Raymond J.
Berg, Torsten Ludwig.
Charity, Jonathan Charles.
Curr, Alexander Manuel.
Dixon, Richard Leslie.
Fenwick, William.
Gordon, Robert Connolly.
Gulick, John Davies.
Harling, Sydney Cyril.
Kidwell, Alfred James.
McAllister, Eugene Patrick.
Purdue, Frank.
Ramsey, Norman.
Stewart, William.
Woodham, Kingston Francis, Lieut.-Col.

Graduates

Anandan, Emmanuel.
Auld, John Gwynne, B.Sc. (Eng.).
Beard, Robert James.
Beecroft, John.
Bindorff, Leonard Lewis.
Blomfield, Owen Hugh D.
Boxall, Reginald Charles, B.Sc.(Eng.).
Buckley, Eric.
Bunting, Ivan Joseph, B.Sc. (Eng.).
Clayton, Thomas.
Cluff, William Vernon, B.Sc.
Curtis, James Eric.
Douthwaite, William James.
Fatehchand, Ramdas Richard T., B.Sc.(Eng.).
Frugtniet, Royston Mervyn L.
George, James William H., B.Sc.(Eng.).
Hart, Henry Edward W.
Hawkes, Edward George.
Howells, John George, B.Sc.
Johns, Rowland Harvey, B.Sc.
Knight, Albert Howard.
Knox, John Edward.
Ladd, Gordon Alexander, B.Sc.
Leaning, Norman William, M.A., B.Sc.
Lee-Richards, Maurice Henry.
Liu, Heng Ling, B.Sc.
Mankame, Ramnath.
Maugham, George Harold.
Mills, Victor Ronald.
Moon, Kenneth.
Morgan, Dillwyn Hywel.
Mosley, Geoffrey.
Neidle, Michael M.
Porter, Walter Albert.
Robinson, Jack.
Rowley, Basil George H., B.A.
Sawhney, Kanwar Sain, B.A.
Stenner, Thomas Edward.
Tate, John Hildyard.
Whiddett, Sydney Douglas.
Whitney, Leonard Charles, B.Sc.(Eng.).
Winstanley, John.
Yarwood, Marcus Fortescue.

Students

Ashby, Charles Bradwin.
Bailey, Alan James.
Baker, William Frank B.
Barr, Robert Greenough.
Basu, Samarendra.
Bedson, Charles Joseph.
Blake, Walter Ernest.
Brignell, Albert Edward.
Brink, Gerrard Edgar P., Sub-Lieut., R.N.V.R.
Brown, Royston Ernest C.
Browne, George Finglas.
Cadman, Alec.
Carter, James Dixon.
Clifton, George Rex.
Close, William Gibbons.
Cross, John Leonard.
Croudace, Charles Gerald.
Cullen, Charles Gavin.
Cullen, Herbert Francis T.
Cummins, Peter Anthony.
Drummond, Ian Douglas M.
Edwards, Maurice Emlyn.
Gasson, Anthony Philip.
Geake, Derek Burt.
Gent, Robert James.
Glasgow, Robert Hamilton.
Goodacre, Ralph.
Goss, William John.
Graham, Robert Arthur.
Griffin, George.
Grounsell, Thomas William.
Harper, Richard Frederick.
Haynes, Ian Thomas.
Heath, Albert Maurice.
Heath, Benjamin George.
Herbert, Alec Edward.
Hibbert, James Alfred.
Hill, John Cureton.
Hodges, Cyril Edward J.
Hodgkinson, Thomas Edwin.
Holland, Algernon Charles.
Holling, Kenneth.
Hooper, Leslie Edward.
James, Wilfred.
Jenkins, Albert Douglas.
Jones, Leonard Louis.
Kershaw, Peter Leslie.
King, Edward Seymour F., Sub-Lieut., R.N.V.R.
Lee, Jeffre Haigh.
Letchford, Arthur William.
Lowe, William Percy.
Lown, Victor William.
MacDonald, Edward Robert L.
McEwan, David Hutchinson, B.Sc.(Eng.).
Moore, George Edward A.
Morton, Richard.
Nightingale, Derek.
Osborne, Edward Hugh.
Piper, Harold.
Platts, Ernest James.
Poulston, Bernard Vincent.
Powell, John William.
Rao, Charles GnanaPrakasa.
Rayner, Stanley Ernest.
Roberts, William Eric.
Robinson, Herbert.
Roper, Dacre Alexander.
Ross, Victor J.
Russell, William Douglas.
Saul, Ezra Meyer.
Saunders, Peter Bakewell.
Shepherd, George Eric.
Sheppard, Harold.
Simkins, Donald Stephen.
Smith, Alonzo.
Smith, Douglas George J., Sec. Lieut., R.E.
Spooner, Archer Michael, B.Sc.(Eng.).
Stovold, Douglas Walter G.
Syal, Bal Krishan.
Thairani, Luxman Bhojraj, B.Sc.(Eng.).
Waters, Stephen John.
Watkins, Charles Gordon.
Wedderburn, William George.
Wilkes, Walter Stanley.
Wilkins, James Humphrey.
Wilson, Arthur William.
Wilson, Philip Sidney.
Wrapson, Frederick George.
Wright, William Frederick.
Yirrell, Ernest William F.
Ziff, Marja Ludwika (Miss).

Transfers

Associate Member to Member

Badham, Leonard Hulford L.
Bennett, Alfred Percy M.
Das, Josiah Prema, B.A., M.Sc.
Dixon, Murray Deighton, M.A
Drucquer, Leonard.
Foden, Arthur.
Freeborn, Charles Fernandez.
Freeman, Charles Frederick, B.Sc.(Eng.).
Frome, Norman Frederick, M.Sc.
Hacking, John.
McPetrie, James Stuart, Ph.D., D.Sc.
Narayanan, Ramaswamy Lakshmi, B.E., B.Sc.
Petch, Herbert Stanley, B.Sc. (Eng.).
Shepherd, James Ernest.
Thornton, Leslie Charles.

Associate to Associate Member

Bloore, Charles George.
Burgess, Samuel Lewis.
Clark, Robert George.
Campbell, Archibald Stewart.
Daniels, Harold Bentley, B.Sc.
Ezard, Gerald.
Griffin, William Smiles.
Hall, Stanley.
Higson, John.
Ross, James Hugh.
Tetlow, Norman.
Waldeck, Thomas Ernest.
Walker, Harold Stephen.
Wilson, Arthur Henry.

Graduate to Associate Member

Abraham, Thomas.
Allan, Charles Lewis C., B.A.
Anderson, Horace.
Anderson, John Rupert.
Archer, Frank.
Batcock, Bernard John.
Beattie, Herbert.
Bell, Albert Geoffrey R.
Bellamy, Alan Arthur.
Benington, Leslie William.
Bentley, Robert.
Billington, Reginald Moreton, M.Sc.(Eng.).
Bird, William Arthur.
Boller, Albert Walter.
Bolton, Stanley Ernest, M.Eng.
Bourne, Harry Kebbell, B.Sc. (Eng.).
Boyne, Samuel Noel.
Braid, Kenneth Edwin P.
Brocklesby, Harry.
Brooker, Kenneth Richard.
Brown, Eric Frank.
Bunce, Leonard Cecil, B.Sc. (Eng.).
Burgess, Alfred Gibbon.
Burton, Leslie.
Capeling, Leslie Frank.
Clay, George Robert.
Craven, Arthur Swift.
Dainty, John William.
Davies, Cyril Llewellyn.
Dawson, Stanley.
Evans, Alwyn.
Fairley, Eric Samuel, B.Sc., Ph.D.
Fawcett, Francis Alfred, B.Eng.
ffoulkes, Arthur Kingsley F.
Fletcher, Ralph Owen, B.Sc. (Eng.).
Ford, Edward John R.
Francis, William Charles.
Gibb, George.
Griffiths, David Lewis.
Gunton, Richard, B.Sc.(Eng.), Sub-Lieut.
Halstead, Frederic John.
Harding, George Nelson.
Hargreaves, James, B.Sc.Tech.
Harris, Albert William, B.Sc. (Eng.).
Heard, Sydney Richard, B.Sc.
Henderson, George, B.Sc.
Hill, Francis Glynn, B.Sc. (Eng.).
Holt, William.
Howarth, John.
Hulcoop, Frank Albert.
Innes, James Albert.
Insley, Leonard Robert.
Jallings, James Harland.
Jones, Arthur Stanley.
Jones, Emlyn, B.Sc.(Eng.).
Kelk, William Hyde H., B.Sc.
Lewis, William Gwynfor.

Graduate to Associate Member—continued.

Lewitt, Sidney Alfred, B.Sc. (Eng.).
Lomax, Geoffrey Raymond.
Macdonald, Montagu Frank.
Mackenzie, William Alexander, B.Sc.
Macmaster, Malcolm Morrison, B.Sc.
Marsh, William Richard, B.Sc.
Mather, John Walter S.
Mather, William Alfred.
Mathew, Fred.
Mawson, Spurgeon.
Mendelson, John.
Miers, Arthur Samuel.
Mills, William Harold.
Milway, Jack Thomas.
Mohindra, Lall Chand.
Murray, Hugh Younger, B.Sc. (Eng.).
Murray, John Bernard, B.Sc. (Eng.).
Neal, Harry, Capt., R.A.O.C.
Nicholson, William Stanley.
O'Donnell, Terence Patrick.
Oldale, Eric, B.Sc.
Osborne, Stanley Frank.
Pelerin, Ronald Percy.
Pine, Angus Floyde.
Platt, Edwin Royston.
Pratt, Frederick Martin.
Railton, Courtenaye Lewis.
Rao, Molahalli Sanjiva, M.A.
Read, William Macartney.
Redclift, Ronald David.
Rice, Norman Richard, B.Sc. (Eng.), Lieut., R.N.V.R.
Ridge, George Royston C.
Roebuck, John Spencer, B.Sc.
Rudd, Harold Crompton.
Scott-Maxwell, Ian Stephen.
Sharp, Andrew.
Sinclair, Kenneth Cameron, B.Sc.
Smeed, George William, B.Sc. (Eng.).
Snelson, John William.
Stevens, Stanley Walter.
Stokes, Clarence, B.Sc.
Sully, Robert Bryant, B.A., Capt., R. Signals.
Swash, Kenneth Norman.
Sykes, Ellis, B.Sc.Tech.
Tapper, Geoffrey William.
Thomas, David Hylton, M.Sc.Tech.
Toner, Harold Norman.
Treasure, Vivian Roy S.
Waine, Ian Leslie.
Walsh, William Warwick.
Watson, Struan Robertson, B.E.
Wight, Robert Durton.
Woodcock, Colin Frederick.
Work, Andrew Leslie, B.Sc.
Wray, Francis D'Arcy.
Yeo, Philip Henry.
Young, Robert Calvert K.
Zoller, Ronald Ernest.

The following transfers were also effected by the Council at their meeting held on the 5th December, 1940:—

Student to Graduate

Abbott, Norman Percy.
Assenheim, Joseph Philip, B.Sc.(Eng.).
Bharucha, Kaikhosru Rustomji, B.Sc.
Blythe, Richard William.
Broadbent, David Travis.
Craig, Joseph Andrew C., B.Sc.(Eng.).
Davies, Harold.
Galloway, Ian Robertson.
Gregory, William Edmund, B.Sc.(Eng.).
Kerr, William Donald, B.Sc.
Kirk, James Mitchell, B.Sc.
Leonard, Cecil Albert W.
Little, Stanley James.
Milne, Frank Alexander.
Roberts, John Arthur, B.Eng.
Roberts, Sydney Idris.
Roper, John Frank.
Shimwell, James Alan.
Smith, Frederic Charles E., B.Sc.
Swanson, John Sydney T., Sub.-Lieut., R.N.V.R.
Tandan, Ram Kumar, M.Sc.
Taylor, Robert.
Toyne, Clifford Clarke, B.Sc.Tech.
Trier, Robert Henry, B.Sc. (Eng.).
Williamson, Denis, B.Sc.Tech.
Zaky, Mohamed Taha, B.Eng.

PROCEEDINGS OF THE INSTITUTION

959TH ORDINARY MEETING, 24TH OCTOBER, 1940

Mr. Johnstone Wright, the retiring President, took the chair at 2.30 p.m. and, before starting the normal proceedings, reported with regret the death, since the last meeting, of three distinguished men in the electrical world —Sir Oliver Lodge, Sir J. J. Thomson and Dr. Charles Merz. Dr. Merz was, he mentioned, a partner of the new President, who would have the sympathy of the members in taking up office in such trying circumstances.

The minutes of the Annual General Meeting held on the 9th May, 1940, were taken as read and were confirmed and signed.

A list of candidates for election and transfer, approved by the Council for ballot, was taken as read and was ordered to be suspended in the hall.

The Chairman announced that during the period May to September 738 donations and subscriptions to the Benevolent Fund had been received, amounting to £690. A vote of thanks was accorded to the donors.

The Premiums awarded for papers during the past session were presented by the Chairman to such of the recipients as were present.

He then moved a vote of thanks to Mr. W. McClelland for the excellent work he had done for The Institution as Honorary Treasurer for the past three years. The vote of thanks was carried with acclamation.

Mr. Johnstone Wright then vacated the chair, which was taken by the new President, **Mr. J. R. Beard, M.Sc.**

Dr. A. P. M. Fleming: The management of a large technical Institution such as ours, becomes in course of time relatively stabilized, so that a President on taking office can foresee the principal duties that he is likely to be called upon to discharge. The session just ended opened on the eve of war, and it was evident then that the normal procedure of I.E.E. affairs would suffer serious dislocation. Decisions had to be made as to whether headquarters should remain in London; whether with the risk of air raids the regular meetings could be carried on; how contact could be maintained in all circumstances with Local Centres; and how best to be of the greatest service to the members under whatever conditions the war might bring about. It was amidst this welter of circumstances for which there was no precedent for guidance that Mr. Johnstone Wright entered upon his term of presidency. The greatest tribute that can be paid to him is that under his guidance The Institution has emerged so successfully through this very trying period. Owing to his native prudence, his wide experience and his very sound judgment, he has at all times been a tower of strength. His year of office will be a memorable one. We are grateful to him for his unfailing labours on behalf of The Institution, superimposed, as these have been, on the very heavy responsibilities of his own very eminent position. The work on which he has been engaged for so many years is now standing four square to the test of war conditions; and without that work, so thoroughly done, it would be questionable how effectively the war effort in this country could be carried on. We appreciate that while bearing the brunt of the Institution affairs Mr. Johnstone Wright has, through war circumstances, been deprived of the lighter social functions which normally brighten and cheer the life of the President. It is with particular pleasure that I move in the terms prescribed by The Institution: "That the best thanks of The Institution be accorded to Mr. Johnstone Wright for the very able manner in which he has fulfilled the office of President during the past year."

Colonel A. S. Angwin: I am speaking to a very time-honoured formula, but the general body of members do not consider the resolution now before you to be in any way a formal matter. We appreciate very deeply the work which Mr. Johnstone Wright has done during his term of office. Owing to the present circumstances, the President has not had as full an opportunity as usual of meeting the members, and the part which he has played in carrying on the work of The Institution cannot yet have come so prominently to general notice; for that very reason we who have seen his work more closely are anxious to emphasize and to put on record how much we appreciate all that he has done during his period of presidency. Not the least of the functions which he has fulfilled during this difficult year is that he has carried on the continuity of the high tradition associated with the office of President of this Institution. It is with great pleasure that I second the resolution which has been proposed by Dr. Fleming.

The resolution was then carried with acclamation.

Mr. Johnstone Wright: I thank Dr. Fleming, Col. Angwin and the meeting for their expression of thanks. I am not sure that the tributes paid me have been deserved, but if I have done anything during my year of office to maintain the high traditions of The Institution I am well satisfied. One tradition seems to be to make the President's task as easy as possible, and I should like to thank all those who have so generously helped me during my year of office. I am sorry that I have not as President been able to make more social contact, particularly with the Local Centres, but that is only one of the pleasures I have had to forgo under war conditions and I hope the Centres will pardon my not being able to see more of them. In the meantime the flag of The Institution has been kept flying and its activities, apart from social ones, have been very little diminished. I had hoped that my term of office would see the end of the conflict and that the new President might take up office under happier circumstances. That was not to be, but let us hope that the end may at least be within sight before the close of Mr. Beard's term. In the meantime I feel the Institution's leadership can be left in no better hands than his. I thank you.

The President then delivered his Inaugural Address (see page 16).

Mr. P. V. Hunter: It is my pleasant duty to propose a vote of thanks to the President for his interesting Address. I feel, however, that before I do so you would wish me on your behalf to offer him a few words of sympathy and encouragement. Mr. Johnstone Wright has referred to the great loss which Mr. Beard has sustained in the death of his senior partner, and I feel that I am in a position to estimate that loss much better than many of those present because Mr. Beard and I were closely associated in Dr. Merz's service some 30 years ago. I feel that I cannot too strongly emphasize the great qualities which Dr. Merz had in relation to those who worked with him, and which no one more than Mr. Beard is in a position to appreciate and feel the loss of. This is not the occasion to attempt to assess the contribution which Dr. Merz made to the electrical industry, but I do feel we should offer the President our sincere sympathy in the loss he has sustained and we hope that he will find encouragement to bear the greatly increased responsibilities which he will now have to shoulder. I feel also that we must extend our sympathy to Mr. Beard for having to take office during this unpleasant time of war, when the work of the President is made more onerous and when those relaxations which in normal times help him to sustain the cares of office are almost entirely absent.

With regard to the President's Address, I think you will agree with me that it is remarkable for several reasons. First, it is well fitted to the circumstances of the time, which have justified his giving his personal views on matters some of us would regard as controversial. I entirely support the views that he has expressed, as I feel sure the majority of those present will do. The Address will appeal to the members from many points of view. It will have the entire sympathy and the wholehearted support of the junior members: they look to the future, and the past does not interest them very much. Personally I was impressed by the facility with which the President expressed his opinions and the conciseness of language which enabled him to make us grasp what he thought. To my mind, that is something on which engineers are not always too happy. The President referred more than once to the fact that engineers are accustomed to find their greatest satisfaction in the interest of their work, and I feel sure that will find an echo in the hearts of most of us. Finally, the Address exhibits the character of the man himself; it shows him in a light which I feel sure will be new to many members who do not know him very well personally. I have great pleasure in moving: "That the best thanks of The Institution be accorded to Mr. J. R. Beard for his interesting and instructive Presidential Address, and that, with his permission, the Address be printed in the *Journal* of The Institution."

Mr. V. Z. de Ferranti: It gives me great pleasure to second the resolution, because I have a warm personal feeling for our President, which I am sure is shared by all the members who know him. The President has had a wide experience in many great ventures and undertakings throughout the world. For many years he has been a focal point through which information has been collected and distributed, and so he has been in an extraordinarily suitable position to widen his experience. We are fortunate in that the President has the mental equipment and the constructive industry to make use of the information which has become available to him, and we have seen the results of that in this Address as well as in the many undertakings with which he has been associated. We have all been very interested in the way in which he has led us through planning in general and in particular in relation to the electrical industry, but I think that we have to thank him most for reminding us that this unhappy time in which we are now living is only a thing of the present, that there is a future and that we have the men and the ideas for making that future a great one.

The resolution was then carried with acclamation.

The President: I very much appreciate the kind words which have been spoken and the cordial way in which the resolution has been received. I am particularly pleased that it has been proposed by Mr. Hunter, as I worked under him during some of the happiest years of my early life when we were both in Dr. Merz's office, and I appreciate more than I can say the words that he used about our late chief. I thank you all.

The meeting then terminated.

960TH ORDINARY MEETING, 14TH NOVEMBER, 1940

Mr. J. R. Beard, M.Sc., President, took the chair at 12.30 p.m.

The minutes of the Ordinary Meeting held on the 24th October, 1940, were taken as read and were confirmed and signed.

Messrs. D. V. Onslow and H. L. D. Wyman were appointed scrutineers of the ballot for the election and transfer of members, and after the scrutiny the President announced that the members whose names appeared on the list (see "Institution Notes," page 12) had been duly elected and transferred.

The meeting then terminated.

INAUGURAL ADDRESS

By J. R. BEARD, M.Sc., President.*

(*Address delivered before* THE INSTITUTION, *24th October*, 1940.)

Each new President on assuming office must do so with three main feelings. First, gratitude to his fellow members for considering him worthy of election to the highest office which the profession has to offer; secondly, some anxiety as to his ability to sustain adequately the high standards of his predecessors and the great traditions of The Institution; and thirdly, firm resolve to use to the utmost his brief opportunity for service. All these I feel to the full.

After a short reference to the wartime activities of The Institution and its members I propose to devote my Address to problems which will arise after the war and to the importance of considering them at the present time. I am of the opinion that such consideration is essential and that it can be given without in any way lessening our war effort.

WARTIME ACTIVITIES

During the past year all citizens of the British Commonwealth have been increasingly absorbed in the common war effort, and not least the members of our Institution. In this war engineering, technological and scientific problems are playing a greater part than ever before and the many branches of electrical engineering have all been directly or indirectly engaged in war activities.

For some years we have had the largest membership of any British professional Institution. During the past year this has exceeded 20 000 and our responsibilities are correspondingly great. I will not attempt to refer to the work of our members in detail, but mention should be made of the particularly strenuous work undertaken by those engaged in the light-current branches. These include those responsible for such vital services as communications and broadcasting, and for the design and manufacture of the apparatus for them and of similar apparatus for the rapidly expanding needs of the Royal Navy, the Army and the Royal Air Force. Those engaged upon research and development in the multifarious new applications of wireless deserve special record.

Some 1 285 of our members are on active service with His Majesty's Forces, but, unlike the position in the last war, almost all of these are engaged in a technical capacity which makes use of their specialized knowledge. Thousands more in this time of "total war" are serving the national cause in other directions. Unfortunately we already have to deplore the loss of some brilliant young engineers, among them several sons of our members and the only son of one of our Past-Presidents.

The bitter experience of 1914–1918, when so much technical talent was wasted through trained men being drafted from productive work into non-technical units, was fortunately taken to heart in good time and, as we all know, some time before war broke out the Ministry of Labour organized the Schedule of Reserved Occupations. This has functioned admirably on the whole, despite a few inconsistencies which are inevitable in a scheme of such magnitude.

The problem of directing technical ability into the most useful channel was also tackled by the Ministry of Labour some time before the war. At the beginning of September, 1938, The Institution was asked to co-operate in the formation of a register of scientists and technical experts whose services could be made use of in the event of an emergency, but owing to the improvement in the international situation at the end of that month no further steps were taken. The Council were, however, of the opinion that such a register would be valuable and, after consultation with the Presidents of the Institutions of Civil and Mechanical Engineers, Dr. A. P. M. Fleming, who was then President of our Institution, formed a Committee to organize the compilation of a register. A form of questionnaire was prepared, but its issue was suspended on receipt of another request from the Ministry of Labour to co-operate with them in the formation of a Central Register. Our own Institution, under Dr. Fleming's leadership, has throughout given great assistance in this work which constitutes one of our most important corporate war services; and of our members eligible for enrolment in the register 96% voluntarily submitted details of their training and experience. During the summer, as you are aware, it was made compulsory for certain categories of essential technical men to place their names on the Register, and these included electrical engineers. The reason for the introduction of compulsion was two-fold; in the first place there was a shortage of certain categories, especially engineers with experience in wireless, and in the second place the engagement of staff by certain classes of engineering firms might be prohibited except through the Central Register. Acceptance of offers of employment by engineers on the Register is still voluntary and the objections of employers to the release of key men are given full consideration; but, no doubt, the continuance of this voluntary basis is dependent on both employees and employers continuing to give first consideration to national and not to sectional interests.

The extent of the Institution's work on the Central Register may not have been very obvious to our members as a whole because its chief use, so far, has been to provide candidates for the Services and the various Government Departments, whose requirements have been largely confined to the light-current side. Some indication of its extent is, however, given by the following figures. Up to the 16th October of this year, 267 orders were

* Messrs. Merz and McLellan.

received, covering 937 vacancies. The Placing Panel, under the Chairmanship of Mr. H. T. Young, held 31 lengthy meetings and put forward 3 816 names, which resulted in the confirmation of 547 appointments; the number is probably higher, as delay occurs before confirmation is obtained. As may be imagined, all this work has placed a heavy burden on the Secretary and his staff.

In addition to work directly connected with the Central Register, The Institution has been active in other directions. It has assisted members to transfer to those technical units of the Services in which their experience can be best utilized. Useful work has been done in initiating training courses in electrical engineering for boys between the time of leaving school and being called up for military service, and The Institution is now assisting the Board of Education in organizing courses of technical education for those serving with His Majesty's Forces whose studies were interrupted by the war. As a result of representations by The Institution, arrangements have been made by the Ministry of Labour and National Service whereby many students have been allowed to complete their courses of study, and engineering student apprentices who have reached a certain stage in part-time engineering courses have been included in the Schedule of Reserved Occupations. We have also endeavoured, though without much success, to encourage the various Government Departments to plan their demands on the Central Register in advance and to initiate schemes of intensive training to cope with the shortage of qualified engineers in certain specialist categories.

Military considerations render it undesirable to make public many of the present activities of our members, but when victory is won there will be technical achievements of great interest to be described and recorded in our Proceedings. In the meanwhile, although our normal meetings are temporarily suspended, we shall continue the publication of papers on general questions and encourage written discussion of them. We hope that, with the co-operation of the authorities, these may include many matters of present interest. Subject to the overriding necessity of not making vital information available to the enemy, it is considered desirable to disseminate as much technical information as possible in order to give the maximum assistance to those who are working on new war-time problems. It is therefore hoped that members will try to spare the time to prepare and present papers which may assist other members in their work and which may prevent that wasteful duplication of effort which is so liable to arise when people work in watertight compartments.

OVERSEAS MEMBERS

Our Institution has always taken a pride in the number of its overseas members and has endeavoured to do all it can to be of service to them. Their number amounts to one-fifth of the total membership and their distribution is shown in Table 1. For many years we have had Local Centres in Argentina and China, and we have 16 Local Honorary Secretaries and 12 Overseas Committees in many parts of the world who are an invaluable liaison between distant members and our headquarters. For some years past much attention has been given to increasing these contacts and to exploring the possibilities of co-operation with the local engineering Institutions in the Dominions and India but, unfortunately, this has had to be suspended owing to the war. Nevertheless, at a time when the joint defence of our liberties in face of the assault on all free

Table 1

GEOGRAPHICAL DISTRIBUTION OF I.E.E. MEMBERS (JUNE, 1940)

			Corporate Members		Non-corporate Members
Canada			40		13
Australia	Victoria	58	216	27	115
	New South Wales	80		47	
	Queensland	32		15	
	South Australia	20		8	
	West Australia	17		17	
	Tasmania	9		1	
New Zealand			194		177
Union of South Africa	Cape Province	58	241	55	230
	Transvaal	143		117	
	Natal	38		55	
	Orange Free State	2		3	
India	Calcutta	62	372	131	1 091
	Bombay	66		223	
	Madras	20		73	
	Delhi	12		39	
	Lahore	26		48	
	Rest of India	186		577	
Burma			19		20
Ceylon			39		45
Hong Kong			27		22
Straits Settlements and Malay States			87		60
Rhodesia			22		18
Near East (Egypt, Palestine, Irak, Iran)			70		79
China (chiefly Shanghai)			49		34
Argentina			38		17
Brazil			29		6
United States of America			53		14
Remaining British countries in	Europe	18	80	6	52
	Asia	2		2	
	Africa	35		18	
	America	24		24	
	Australasia	1		2	
Remaining foreign countries in	Europe	92	250	36	142
	Asia	48		46	
	Africa	25		24	
	America	85		36	
Total overseas			1 826		2 135
Great Britain			8 120		7 914
Northern Ireland			62		65
Eire			90		42
			10 098		10 156
Grand total			20 254		

peoples is forging still closer the links of the British Commonwealth of Nations—and, indeed, of all English-speaking peoples—I am sure you would wish me to take this opportunity to let our fellow members overseas know

that they are often in our thoughts. Those in the Empire will be taking a share in the war-time activities of their various countries nowise less important than the work of our members at home, and we would wish them to know that this is recognized and appreciated. We look forward, after the war, to renewing plans for closer collaboration.

PLANNING THE POST-WAR WORLD

At a time such as the present it seems inappropriate in a Presidential Address to deal with past achievements, and inadvisable to deal with questions directly bearing on the war. It is, rather, an opportunity for encouraging our members not to limit their thoughts entirely to the immediate problems of the war, even though most of their normal activities must necessarily be so limited, but to give earnest consideration to the replanning and reconstruction which must follow the war. To be effective such consideration must be given *now*, so that we and our friends may know in more detail the kind of world we are fighting to attain and the nations which are now our enemies may know what kind of peace is possible.

We, as engineers, must of necessity be called upon to play a major part in rebuilding the world, and we must prepare and equip ourselves for this task now. While our individual activities will necessarily be of a specialized character, these can be more efficiently carried out if we keep in mind, as a background, the fundamental problems of planning in general. Some of my predecessors in office have already stressed the importance of engineers broadening their outlook and taking more interest in the wider activities of society. With the encouragement thus offered I hope you will allow me in this exceptional year to devote the earlier part of my Address to the planning of the post-war world from a wider aspect than the technical problems of electrical engineering.

I am the more tempted to do this because exactly 20 years ago I gave an address, as Chairman of our North-Eastern Centre, on "Post-war Conditions and Developments, with particular reference to the Electricity Supply Industry."* On re-reading this to-day it is evident that purely technical achievement has fulfilled, and in many cases exceeded, the expectations then expressed. Where we have largely failed is in having no clear idea of the purpose for which those technical achievements should be used, and also in lacking ability to arrange that co-operation with non-technical people and interests which is necessary if the engineer is to produce the structure that he knows to be most efficient and useful to the community.

As a starting point may I assume that we all recognize that the war has brought about, and is bringing about, tremendous changes not only in our environment but in our whole outlook, and that we are all prepared to agree with that sober organ *The Times* that—

> "To liberate Europe from Hitler does not mean to reverse the whole process of economic integration which has been set in motion. . . . Much harm may be done to our cause, both in Europe and oversea, by the insinuation that we stand for the old order and that our only aim is to restore the *status quo* in Europe and to maintain it at home. This charge should be emphatically and authoritatively refuted."

There is herein implied some, possibly belated, recognition that the old order was no longer producing a healthy and happy community and that, for one reason or another, apathy, selfishness and discontent, too much freedom in some directions and too little in others, were gradually undermining the character and vigour of the democratic nations. The malaise from which these nations have been suffering is aptly summed up by the eminent American writer, Walter Lippman:

> "The muddle of the democracies comes from something deeper than their form of government; it comes from the gradually accelerated destruction of all convictions about the nature of man and his destiny. . . . For how can this planet be governed by people who have ceased to believe that there is good and that there is evil?"

The growth of the *Fuehrerprinzip* undoubtedly received its impetus from this failure of democracy to realize those aims which its founders originally set before them, and it would be folly to belittle the extraordinary vigour and achievements of these modern movements. They have made a strong appeal to those who felt frustrated by the hesitations, resistance to change and lack of clear purpose exhibited by the pre-war democracies—an appeal more particularly felt by youth. These movements have been accompanied, and made possible, by patient, sustained, intensive planning such as the world has never previously known and which would have produced a revolutionary improvement in society if it had been governed by noble ideals.

Unfortunately, the *end* to which this planning has been applied in most totalitarian countries is domination by groups of ruthless mal-educated men, who have played on the cruder nationalist feelings of people embittered by adversity and have exploited the unselfish instincts of the masses for base purposes. They have not sought power for the good of their fellow men but as an end in itself and for the sheer joy of exercising it in selfish, boastful and brutal fashion. Emboldened by success, their ambition has soared to the domination of other nations until, in Germany, we see a vast attempt to enslave the whole western world. The *means* by which their plans have been carried out are equally evil; by terror, by persecution, by cruelty and by subtle lying. The British loathe this so-called "new order" with all their heart and soul and intend to stamp it out for ever as an unclean thing. In their fight to do so they have the growing support of all free people, and especially of that great free people across the Atlantic. But as we are agreed that there can be no return to the "old order," it becomes of paramount importance to consider what kind of order we intend to set in its place.

The events prior to the outbreak of the war and the experience during the war have brought to the English peoples an awakening to their past failures and a wide desire to build a better society after the war. We know that we must prepare and plan for the post-war period if we are to avoid a repetition of our failure after 1918 and not again sow the seeds of future conflict. We know that

* *Journal I.E.E.*, 1920, 59, p. 30.

we must not, as in 1918, try to rebuild the pre-war world. We know that we have learnt from our enemies the immense power of planned development, but that we must use and turn it to nobler ideals. We know that the post-war period cannot be visualized as a period of "peace" in the sense of tranquillity and repose, but, on the contrary, must be a continuation of the present struggle for constructive, rather than destructive, purposes. Knowing these things we feel that "our feet have been set in a broad place" and, mingled with all the sorrow, anxiety and suffering, we are conscious of a sense of exhilaration that we are living through one of the great turning points of human thought and action, in which the lowliest individual has his part to play. As Mr. Churchill has said in two of his inspiring phrases, "the right to guide the course of world history is the noblest prize of victory" and "when this war is won the life of the world may move forward into broad sunlit uplands."

Are we to be worthy of our calling? Not unless we devote much intensive thought to the ideals which we desire to see established; unfortunately, such ideals tend to be blunted by the experiences of protracted war. Nevertheless, amidst all the confusion of thought, certain broad principles begin to break through the murky turmoil. I think they have best been summarized by another American writer, Dorothy Thompson, who suggests that the primary origin of the war was the secession of Germany from Western civilization and that we are fighting a great civil war to force Germany back into it. This Western civilization she defines as follows:—

> "It is not democracy, not parliamentary government and certainly not capitalism. All of these are merely manifestations of something else—temporary forms to express a more permanent content.
>
> "Western civilization is, nevertheless, definable. It is the synthesis of three things: The Christian ethic; the scientific spirit; and the rule of law.
>
> "The essence of the Christian ethic is that the weak have rights as well as the strong, and that the strong must set limitations on their own power.
>
> "The essence of the scientific spirit is that the search for truth transcends the State and may not be limited or suppressed by the State. It presumes the separation of State and culture, i.e. the separation of culture from force.
>
> "The essence of the rule of law is that contract is superior to arbitrary force; it presupposes a continuity of relationships . . . from whose sovereignty no one is exempt, not the King, not the President, not the powerful, nor the weak."

The importance of setting some such ideals before us arises from the general acceptance of the fact that the necessity for planning will not cease with the coming of peace and that all planning must have an end in view. We all realize that modern warfare can only be successfully conducted by national planning. Even those of us who jib most at the "mistakes of bureaucracy" admit that the overall results of wartime planning far more than balance the errors made in carrying it out and that it is possible, by experience, gradually to correct such errors. There is no reason to think that planning would be less efficient in times of peace, but the important difference is that in war the object is clearly defined and universally agreed. Planning, therefore, becomes relatively easy because its discipline is willingly accepted by all for the common good. We can only get such willing acceptance of peace-time planning if we have an equally wide agreement as to its aims. Hence the need for the general acceptance by society of common ideals.

Engineers and scientists have been largely responsible for that immense technological progress which, as has been said with some element of tragic truth, "has merely provided us with more efficient means for going backwards." Are not those same engineers and scientists largely to blame for being interested mainly in their technical and scientific discoveries and developments, and for giving only superficial consideration to the uses to which these are put? They have, indeed, rather taken a pride in being superior to politics, forgetting that politics control the all important art of governing mankind. At the same time they all feel in their bones, and often say amongst themselves, that they are more capable than anyone else of dealing with the day-to-day problems which arise in running the world. Observation and experience lead me regretfully to feel, however, that we engineers are a somewhat narrowly educated and over-specialized section of the community, often with an unfortunate tendency to disparage ethical and spiritual values and to scorn as "highbrow" those branches of knowledge known as the "humanities." This is the more unfortunate because many of us have been led into our profession by certain natural aptitudes for logical thought which have been further enhanced by our training and which, if properly used, might be of immense value to the society in which we live. These can, however, only be fruitfully applied to communal use by widening our ideas and by training ourselves for political action in the wider sense. May I, therefore, stress again, as so many of my predecessors have done, the importance of such wider education and training of our younger members and recommend to them the study of that great wealth of literature dealing with social and moral problems which lies ready to hand. I, myself, have found much inspiration from such books as Sir Richard Livingstone's "Greek Ideals and Modern Life" and Aldous Huxley's "Ends and Means." One may not agree with all their theses, but they are not difficult to read and certainly stimulate thought on such problems as we now have before us.

PLANNING IN A FREE SOCIETY

Can planning be compatible with a free society? I would answer in the affirmative provided freedom be correctly interpreted as freedom of individual thought, speech and action in so far as it does not conflict with the rights of others to similar freedom and with the general freedom of the society in which we live. This qualification is vital and far reaching and its detailed study would carry us far beyond the confines of a Presidential Address. It has difficult implications of the need for qualities of altruism, unselfishness, tolerance, and even humour, but it is fortunate that human nature is so constituted that the exercise of these is reinforced by motives which appeal to the self-interest of the individual. As examples of such motives I might mention three:—

(1) Despite human failure to learn from experience it has been proved again and again that true happiness is most often attained when it is unsought, and that it is, indeed, a by-product of thought for the happiness of others.

(2) It is not the goal but the struggle which satisfies and, therefore, we may as well have the moral satisfaction of setting ourselves an unselfish goal.

(3) The happiness to be derived from assisting to do a job which is worth doing and from doing it efficiently is considerable, and is still greater if it is being done more efficiently than it has been done before.

However, we must not assume too ready acceptance of such purely ethical or philosophical motives for our planning to the exclusion of what, in our present imperfect world, is one of the main incentives to human effort. I refer, of course, to the acquisition of power to control men.

We are all actuated by each of these incentives in varying degree; and although, in an ideal society, the more altruistic ones would presumably be universal and overriding, it must be accepted that the " acquisition of power " motive must remain powerful for long to come. In our present society it cannot be considered to be inherently bad in itself, but it can be bad if allowed to operate unchecked, as has often happened in the past. Our plans should, therefore, embody it but must include adequate safeguards to ensure that a proper proportion of the efficiency it produces shall enure to the public good, and that it does not restrict the basic freedom of the individual as defined above.

Power over others can be acquired either through money or through position. Undoubtedly the earning of profit to acquire money power has sometimes been grossly abused or has been allowed to distort policy. But we should take care lest, in reacting to such abuse, we swing over too readily to the alternative of obtaining power through position. This can be equally harmful if unchecked and would seem to be a great danger at the present time, even under cover of such high-sounding terms as public ownership and nationalization.

It will be clear that planning in a free democratic society must be approached primarily by educating those affected so that they appreciate its benefits and the higher freedom to which it can lead and so become willing to subordinate individual idiosyncracies to the good of the whole—including themselves. Almost invariably, however, in this imperfect world this must be supplemented by reasonable power to prevent a recalcitrant minority from stultifying a plan which the large majority recognize as essential for fuller freedom and efficiency.

I suggest that our comparative failure to plan efficiently during the last 20 years has been due to two causes. The first has been an excessive tenderness towards small, but influential, minorities. Even a very limited degree of compulsion has often been accompanied by so many checks and safeguards as to make it almost unworkable and exceedingly slow in action. We must undoubtedly be prepared to adopt a bolder policy in such matters in the future.

The second has been a lack of clear purpose in our national educational system. In place of training for citizenship we have concentrated on producing mere compendia of knowledge, our students spending the greater part of their training period under the shadow of written examinations on subjects which they discard and largely forget as soon as they are free to do so. The planning of improved education must be one of the first jobs of the planners and therefore merits some consideration. In order to make democratic institutions a success the chief qualities required, in ordinary citizens and leaders alike, are the capacities to think clearly, to analyse impartially and to appreciate culture, and we must design our educational system accordingly. We must also aim at producing men who, while not mere compendia of knowledge, know where to put their fingers on information when they require it, who realize the necessary limitation of individual knowledge and are willing to learn from others, and who are equipped with sufficient general understanding of other fields of activity than their own to enable them to appreciate the meaning of advances in such fields and to accept their incorporation in the general plan.

Such a basis of education is necessary for all citizens, but particularly for those who will become the leaders who have to devise and carry out the planning. With such a background they will be less likely to fall into the trap of over-simplifying human problems, or to look for fullest efficiency from rigid centralized planning imposed on unwilling units at the risk of social violence. They will recognize that human conservatism exists, and that often the most useful results are likely to flow from extending and adapting existing institutions and from applying well-tried and accepted principles to wider fields. They will know that a freely accepted development is more likely to be permanent and to extend than any enforced and theoretically complete plan.

Although it is so desirable that these somewhat negative and passive qualities should be developed in the education of our leaders it would be disastrous if they were not combined with those positive and active qualities of leadership to which I refer later when I come to deal with practical planning. It is the frequent lack of these which is a recognized weakness of our otherwise admirable Civil Service.

Despite occasional lapses, these educational principles seem to have been widely instilled in those leaders of the British people who have worked so successfully in the development of the British Empire, a particularly able summary of which is given in Prof. Ramsay Muir's booklet on " The British Empire; how it grew and how it works." This political development indicates that our nation has the inherent capacity for large-scale planning, although we have so often failed consciously to exercise it. It also indicates that our public school system, whatever its defects, has many of the essential qualities, and it is to be hoped that those changes in the public school system which seem inevitable after the war will not result in their loss.

It seems to be when we have had to deal with economic, social and technological matters, both at home and in the Empire, that we have failed to plan with sufficient courage and foresight. In so far as this is due to defects and narrowness in our scientific and technical educational system, it indicates the vital necessity for overhauling and replanning it.

A contributory cause to such failure has been that many of those who accept the desirability of more extensive

planning have been repelled from endeavours to give their ideas constructive form by the tendency of many planning enthusiasts to indulge in theoretical planning of an over-simplified type and on a scale which large sections of the population are not at present prepared to accept. I would urge the importance of avoiding this mistake of over-simplification for the very practical reason that it implies excessive centralization, which, as experience shows, usually leads to vast bureaucratic organizations, bound in red tape, slow and inefficient in action and coldly impersonal in spirit.

These disadvantages are not so apparent in those occasional instances where the ultimate control is in the hands of a man of outstanding genius for organization and leadership; but such men are few, and it seems to me that one of the errors of the super-planners is to assume that they exist in large numbers. Indeed, one of the most vital and urgent needs of the future is to develop more efficient means for finding men possessed of these rare inborn characteristics, for providing them with an environment in which they can develop, and for training them so that they can be most efficiently used. In other words, we must plan the planners.

This leads me to a point on which I feel strongly. It is that much greater use should be made of the experimental method in planning if we are rapidly to get our planning on correct lines.

The spectacular advance in the physical sciences is based on the change of outlook usually attributed to Francis Bacon, who attacked the methods of science of his day and urged the method of induction and experiment as opposed to that of deduction. In brief this means that, given an effect, the scientist should work backward to the cause and then experiment to discover whether the presumed cause produces the effect. Bacon saw that the real object of science is to find out the force of causation and that progress must be based on *experiment*. The method of scientific reasoning in vogue in Bacon's time, which he attacked so successfully, was to accumulate instances without following any rule of selection. In other words a theory was found and then was supposed to be proved if instances could be accumulated which agreed with the theory. To the engineer this appears to be the method of many planners of to-day and, on the analogy of experience in the progress of the physical sciences, it is a method which is three centuries out of date.

Experimenting implies the possibility of mistakes, but we have perhaps been too cautious in our planning owing to the fear of making such mistakes. I should like to see our problems attacked in simultaneous parallel ways, with the object of testing them by practical trial and error and thus evolving the successful solutions with the least possible delay. One overriding problem which should be so tackled as a matter of extreme urgency is the planned adjustment of consumption to production, which is essential if we are at last to banish trade-depression cycles and the spectre of unemployment. Every thinking man must refuse to accept as permanent a state of affairs in which a large proportion of our main asset—human labour and intelligence—remains unused at the same time as vast numbers of the population are suffering from under-consumption, and even actual want, which could be remedied by the properly planned use of our surplus resources. It is a huge problem but surely not insoluble if we are prepared to tackle it in a communal spirit and with the ideals I have, however ineffectively, tried to outline.

PRACTICAL APPLICATION OF PLANNING

Hitherto I have been dealing with planning in a very broad sense, but engineers are practical people and you will ask "What are the concrete objects for which we must plan?" I have already indulged freely in quotation, but no words of mine can better the answer given in the following extracts from *The Times* leader of the 5th August last.

"The national standard of living stands urgently in need of an overhaul; for, however depleted our resources, there are some whose standard not only cannot be lowered but must imperatively be raised. This will dictate the aim. Attempts in the past to get the economic machine back into gear have gone awry because we thought it enough to organize and stimulate production, bringing upon ourselves the anomalies of 'under-consumption' and 'poverty in the midst of plenty.' The consumer has too long been the stepchild both of economists and of politicians. What will be needed most of all when peace is restored is planned consumption."

"Scientific research into standards of nutrition has been actively pursued during the last decade. The application of approved standards of nutrition to the whole population is the necessary and elementary starting point of a long-term social programme, whose goal must be the extension to all, as a first call on the resources of the whole community, of decent standards of housing, of clothing, and of other amenities of life."

"The experience of Europe after Versailles proved that no political superstructure will endure, however noble the ideals which inspired it, if the social and economic foundations have not been well and truly laid. The first task of the makers of the coming peace must be to dig those foundations. They will be confronted with a devastated, uprooted, famine-ridden Europe. The first step towards the creation of a new European order will be to feed the hungry, to clothe the naked, and to house the homeless. No frontiers, no national rivalries, can be allowed to impede this essential task. The old motto 'To each according to his needs' is the only criterion which can be applied. The European problems of nutrition and housing will be infinitely graver than any which need reasonably be anticipated in this island. But they will not be different in kind; and Great Britain, in tackling the problem of her own reconstruction, will become the natural leader in the reconstruction of Europe. Nor are the two tasks separate and independent. The replanning of European production is a condition of British prosperity; and both are in turn bound up with the resources and the markets of the great countries outside Europe. The rapidity of recovery after the war will depend everywhere on the right distribution of resources."

"Great Britain cannot assume the position marked out for her at the end of the war as the leader of Europe, cannot even remain for long a Great Power, if she loses

the faith to reproduce her stock. Here then is an urgent and unescapable problem. Nearly every one agrees that the State must take responsibility for adjusting working-class incomes to the needs of a family, which they do not at present suffice to meet. We cannot afford to permit a further postponement of this measure of social justice through petty disagreements about the form of the allowances. Income-tax payers already enjoy a welcome admission of the principle; but in present conditions the concession is too small to be more than a palliative."

In all these activities electrical engineers can take their share, especially in assisting to promote decentralization of industry, the happiness and prosperity of our rural communities, the comfort of our homes and the freeing of our women from unnecessary toil, an important aspect of which is the elimination of smoke and dirt.

Practical planning has been studied in much detail by that very able organization " P.E.P.," which is probably familiar to many of you. I am sure you would all find a study of its publications both valuable and stimulating. These have covered a large number of the broad divisions under which practical programmes for planning will have to be considered and which may be summarized as follows:

(*a*) Financial and economic arrangements, including such international matters as currency and tariffs.
(*b*) Education and social services dealing with the training, health, housing, nutrition and recreation of the community and its individual members, whether workers, mothers or children.
(*c*) Public services such as railways, gas, electricity and roads.
(*d*) Industrial production.
(*e*) Agricultural production.
(*f*) Distribution of industrial and agricultural products.
(*g*) Research and statistics.

In classes (*d*), (*e*) and (*f*), planning would, no doubt, be restricted for the present to those products essential to the life of the community.

Having settled a programme in any of these fields, definite action is necessary to carry it out, and definite action entails a proper organization for each service or industry. These organizations must not be only on paper but must consist of human beings, and those dealing with industries must obviously be so arranged as to cover the study of markets and costs, including such questions as consumers' preferences, type and design of products, obtaining raw materials, methods of manufacture, design and building of factories, organization of operating staff, fixing of prices, disposal of profits and raising of capital.

In planning such programmes for industry, much can be learnt from the experience we are having in planning industrial production for war purposes on an immense scale. This certainly has shown the importance of breaking down the excessive parochialism and individualism which has hampered us in the past, but another important lesson is the delay and the damping of individual initiative and enthusiasm inherent in excessive centralization of authority. Planning must not be treated as synonymous with centralization and I feel sure we all agree with the plea of Sir Alexander Gibb, when President of the London Chamber of Commerce, that centralized controls should provide for prompt and reliable decisions and for the delegation of authority.

Such delegation must, however, be combined with machinery to prevent or correct un-coordinated action by individual groups, which inevitably leads to waste of effort. This points to the necessity of some form of correlation of planning authorities by a national planning council or an " economic general staff." Such correlation is quite beyond the capacity of Parliament itself or any existing Government department, and yet it is essential because each industry or service will be found to be dependent to a greater or lesser extent on all the others. As examples, town-planning is dependent on location of industry, exporting industries on foreign policy, agricultural production on wage levels, railways on road transport, and so on almost indefinitely.

In industrial planning we must freely accept the fact that the day of small organizations and free competition is rapidly passing. Modern economic and industrial development demands inexorably the organization of both production and distribution on an ever-increasing scale, accompanied by the elimination of wasteful competition and a wider extension of monopolistic concerns. Such large-scale operations bring in their train an increasing necessity for some degree of centralized planning, and it has been proved again and again by actual experience that it is in providing the minimum necessary facilities for such planning that it becomes necessary to introduce some compulsion of minorities. In their turn the interests of the community as a whole demand some impartial general control of such planning, whether carried out under private or public ownership, to ensure that the resulting economic advantages are not retained by the few but are distributed fairly over the community. The principle of control of monopolistic concerns has, however, been recognized in this country for many years; the present problem is, rather, how to combine encouragement of the elimination of wasteful competition with development of incentives to efficiency which will take the place of those incentives that existed in the smaller organizations and under free competition.

Hitherto the success or failure of any industrial enterprise has usually been settled by whether it is sufficiently sound in all directions to stand up to competition. In the competitive system success means profit, failure means bankruptcy. The men responsible for achieving such success are invariably those who have organized their enterprises most efficiently in every detail and aspect, and even if competition is largely abolished success must still mean similar efficiency throughout the concern, with no waste of men or materials. Hence the essential qualities required by competitive enterprise will still be needed, especially as a monopolistic concern will tend to be on a larger scale; the place of men with such qualities cannot be taken by scientists, technicians or politicians.

It is, therefore, worth considering what these qualities are. They are primarily (1) imagination, (2) correct judgment, (3) rapid decision and (4)—perhaps most important of all—ability to choose men. The lack of all or any

of these is a fundamental fault which spells disaster in private enterprise which has to meet competition, but, unfortunately, some or all are frequently lacking in non-competitive concerns and in Government Departments. It is omission to grasp the importance of these matters which is so lacking in many of those who talk about planning, whether they be writers, engineers or scientists.

Correct judgment is the power to grasp and sum up all the factors in a situation and, having done so, to settle a correct line of action. But, correct judgment must be followed by decision. One of the most frequent failures at the top results from fear of coming to a wrong decision. This results in delays and waste and, unfortunately, in a Government Department or a public concern, as distinct from private enterprise, these failures can continue to take place without disaster to the administration itself however disastrous they may be to the community.

If we want to be successful planners we must not leave out the men who to-day control competitive enterprise. We must insist on their coming in and we must give them sufficient interest and support to make their job as interesting as under the older private enterprise conditions, with not too much "red tape." It is the interest of the work and not the reward that encourages and brings out the best in nine human beings out of ten.

While the qualities which I have enumerated are essential in the head of a concern and in the heads of departments and sub-departments, they are not so essential in the subordinates, and this is why conciliatory and less-determined people are frequently very successful as assistants but fail as heads.

Another parallel approach to the problem of efficiency in large organizations of non-competitive character is through statistics. In other words we must substitute competition in *results* for competition in *profits*, and in order to get such competition in results adequate statistics and good statistical analysis are essential. Good statisticians are, however, rare and it is important that attention should be directed to training suitable men for this work. There are three great dangers. Statistics may be accurate in themselves but so presented that they give a misleading picture. It is a well-known saying, for instance, that "anything may be proved by statistics." Another danger is that they may be too voluminous and detailed. It is essential that they should be carefully summarized and the crucial data given prominence. The third danger is that they are often either out of date or so belated that much of their usefulness is lost. Promptness in the preparation of statistics is dependent not only on the statistician's own work but also on his success in organizing the procedure for obtaining the basic information and getting across to the operating people the real importance of prompt returns. This can be greatly facilitated by periodical revision of the requirements and by the elimination of all non-essential figures. Nothing is more annoying to busy operating people than filling in endless figures of which they cannot see the use.

In this question of statistics the electrical supply industry has set an example to other industries and, although not yet perfect, the statistical work of the Electricity Commissioners has already been of great service in advancing both the technique and the organization of the industry.

ELECTRICAL PLANNING FOR GREAT BRITAIN

I turn now to the application of these general principles; to the planning of those activities with which our members are specially concerned. Such planning will no doubt be required in all branches, but, as I am not competent to deal with manufacture or with the important and extensive field of telecommunications, I must restrict my suggestions to electricity supply, with which my work has chiefly been associated. What is done in this field is, however, of direct interest to the manufacturing side of the industry, as its prosperity is bound up with that of its main customer and with the extension of the general demand for electrical apparatus.

There can be few among us who do not feel that some improvement of organization is essential in the electricity supply industry, although there is naturally some divergence of opinion as to the form it should take. I would, however, urge that the need for initiating action should be accepted by all concerned and that we should make up our own minds as to what should be done. We must not again, as has happened in the past, wait until a scheme is sought to be imposed upon us from outside and then exhibit to the world a picture of diverse interests whose main concern seems to be the preservation of sectional rights and privileges.

To avoid this, a small "Planning Council for Electricity Supply" might well be set up voluntarily by the industry itself on a representative basis (possibly with an independent chairman chosen by themselves), the members being vested by the different interests with full authority to hammer out a mutually acceptable scheme, which could then be presented to the Government for any necessary legislative enactment.

In our membership we have men concerned with all branches of the industry who have knowledge of its weaknesses as well as of its possibilities. I suggest that they have a great opportunity to take the initiative in forming such a Planning Council on the basis of sinking sectional interests and planning for the good of the whole. Its members would only reach an agreed scheme by a process of adjustment involving "give" as well as "take"; but surely it would be worth while to give freely in order to avoid allowing our future to become the sport of party politics and the experimental ground of doctrinaire enthusiasts. A well-considered scheme, with the full weight of the electricity supply industry behind it, could not be ignored by the Government and would probably be welcomed as a speedy means of settling one of the post-war problems, thus clearing the ground for the settlement of others equally urgent.

In putting forward some considerations which might be taken as the basis of such a scheme I must, of course, do so in a personal capacity and not as representing the considered views of The Institution or of any branch of our profession. Nor should my suggestions commit me irrevocably, for we all should approach a discussion such as I envisage with minds open to conviction and compromise; but I am convinced that now is the time to discuss such future planning freely, openly and frankly. Members may not agree with some of my suggestions, but I hope all will give me credit for trying to take that broad impartial view which is the only view your President is free to take.

From what I have already said it will have been evident that I am not one of those who wish to see set up a vast nationalized organization, but I recognize at the same time that certain aspects of electricity supply must be planned nationally if we are to secure the highest efficiency. I equally recognize that efficiency is not necessarily to be achieved by rigid ideas of ultra-uniformity and symmetry of structure or merely by magnitude of organization. No one questions that such services as the telephone or broadcasting are best organized on a national basis, because there is one uniform requirement to be fulfilled and what is done in one part of the country inevitably affects those throughout the country for whom the service is provided. Even so, some measure of decentralization has been proved to be essential to efficiency, and we have all seen the beneficial effects of the adoption of this policy in the Post Office and certain other national services.

It will also have been clear that I am not one of those who feel that there is something fundamentally wrong in any trace of the profit motive being retained in the provision of a public service, provided that it is accompanied by adequate safeguards. With these guiding principles in mind we can now proceed to consider the matter in more detail.

The criterion of the successful provision of any public service is that the consumer can get what he requires in quality and quantity at the lowest possible price. As electricity supply is a public service which, if it is to be efficient, must be operated on a monopolistic basis it follows that it must be subject to a substantial measure of supervision by the State in the interests of the public. Such supervision must form part of any scheme of improved organization.

The industry itself has tended more and more to divide into two parts, one dealing with generation and transmission in bulk and the other with the actual distribution to the ultimate consumers. This division has assumed a very definite character since the Central Electricity Board was set up and has become responsible for bulk supplies to all distributing authorities. It is therefore convenient to consider these two sections of the industry separately. Any scheme will accordingly divide naturally into three parts—national supervision, generation, and distribution.

NATIONAL SUPERVISION

Immediately after the 1914–1918 war the Electricity Commissioners were established to promote, regulate and supervise electricity supply. To those who remember the confused situation in the early days the improvement which has thereby been effected must seem very great. It is of interest to note that the Government adopted a new technique of control; in place of a department of the Civil Service they set up an independent body which, though organized largely on civil service lines and responsible to the Minister of Transport, retains a certain measure of independence and is a direct charge on the industry it controls. This has resulted in placing on the Commissioners a certain obligation to consider the point of view of the industry in so far as this does not clash with the interests of the public. After more than 20 years' experience, it is desirable to review the powers and duties of the Commissioners in the light of the changed conditions which have developed, and it will not be out of place to consider broadly what part they should play in the future.

The Commissioners are, and should remain, a technical-judicial body entrusted with the oversight of the electrical requirements of the general public and of the relations of the activities of electrical undertakings with each other and with the community. The implications of these functions are very extensive and it may be useful to attempt a summary of them. The duties of the Electricity Commissioners would seem to be:—

(1) To advise and guide the Government on all legislation affecting the industry and to endeavour to ensure that their advice is implemented.

(2) To ensure that, so far as reasonably practicable, electricity is available to all and at the lowest possible price.

(3) To ensure that it is available in the form required, which, in general, means alternating current at 50 cycles per second at a standard voltage.

(4) To ensure that it is supplied at a price which is fair as between different classes of consumer and on a form of tariff which is generally acceptable and understandable.

(5) To impose regulations on electricity supply undertakings to ensure that in carrying out any works they do not create any undue danger or nuisance to the public.

(6) To arbitrate between the public and the industry in all matters where it has been found essential for the Government to grant compulsory powers to supply authorities, so that the general good of the community shall not be hampered by unreasonable obstruction from sectional interests. This, in practice, means principally questions of wayleaves and the purchase of land.

(7) To approve the forms of constitution and spheres of operation of supply authorities. The forms of constitution include all financial safeguards necessary for a continuing monopoly, such as the methods of raising capital, scale of depreciation and limitation of dividends.

(8) To supervise the activities of such authorities in order to see that they carry out their duties in accordance with their powers.

(9) To arbitrate on matters in dispute between supply authorities.

(10) To record and study the results of the operations of the supply authorities and to make public comment on the efficiency of the services they perform.

(11) To make grants for research and development in matters which are accepted as of general interest to the industry as a whole but which, for one reason or another, cannot conveniently be organized by the supply authorities themselves.

These duties cover such a wide field and the Commissioners' powers of ultimate control are so great that it is most desirable that they should continue to leave to the various supply authorities wide freedom of planning and initiative in the operation and extension of their undertakings. Nevertheless, in any future planning of the industry it may be desirable that the interpretation of these duties should be clarified in certain respects, greater

emphasis being placed on some than has been the case hitherto and, perhaps, less emphasis on certain others. These points are most conveniently dealt with in detail when I come to consider generation and distribution respectively.

GENERATION

The experience of the 1914–1918 war, which resulted in the formation of the Electricity Commissioners, also showed the importance, for reasons both of efficiency and also of security, of planning generation for much more extensive areas and loads than those of most of the existing supply authorities. Such a policy had been advocated in this country for many years by engineers with vision and was being increasingly adopted abroad. Its adoption in Great Britain had been frustrated by antiquated legislation and local jealousies, and one of the primary duties originally laid down for the Electricity Commissioners was to remedy this state of affairs by setting up Joint Electricity Authorities on a public ownership basis to deal with generation over wide areas.

Public opinion, however, was not ready for such a wholesale transfer of an important section of an industry to public ownership, particularly as it would have had to be done in defiance of the general wishes of many of its leaders. In consequence, Parliament would not grant compulsory powers and the Commissioners found it impossible to carry out such a policy by voluntary means. From a purely technical standpoint this may have been unfortunate, but, looking back over the intervening years, it is evident that the technique of public ownership was then inadequately developed and that had such bodies been formed compulsorily their structure would have been clumsy and inefficient.

It soon became evident that the efficiency of the industry was suffering to an increasing extent from the chaotic state of its generating methods and that some action was essential. In 1925, therefore, a fresh attempt was made to solve the problem by the Weir Committee. The technical development of the industry in the intervening years had, however, shown that maximum efficiency of generation required planning on a national rather than regional basis, and this new development was recognized by that Committee. Their main recommendation was that a Central Electricity Board should be formed to organize generation for the whole country. This was carried into effect by the 1926 Act, which forms a landmark in the development of all forms of public enterprise. It has given the country valuable guidance in working out what has, so far, proved to be the best constitution for a type of organization which was increasing in number and importance before the war and is likely to play a still more important part in the future.

The Central Electricity Board as planned by the Weir Committee has shown itself to combine in a marked degree the best features of both public and private ownership. This is mainly due to the Board having been allowed to manage its finance and administration in comparative freedom from external control, but an important contributing factor to the success which has been achieved is the personal one. Most previous bodies of this character had a large membership formed of representatives of all the numerous interests which were directly, or even indirectly, affected and the individual members frequently served for very limited periods. The Central Electricity Board, on the other hand, is a compact body of only 8 members appointed for definite extensive periods and formed of members carefully chosen by the Government for specific qualifications of a completely non-political character. It is no doubt due to these reasons that the members of the Board have worked together in a true team spirit and, by remunerating the executive staff in a manner comparable with that current in industrial undertakings, have been able to draw on the highest administrative, technical and commercial experience available.

The first duty of the Board was the construction of the Grid. On the purely technical side the result of the intensive work put into the design and construction of the Grid has proved most successful, not only in its actual application in this country but in its indirect effect on the standing of British engineering construction and operation throughout the world. It has also aided our manufacturing industry in extending and consolidating the engineering export trade with the Dominions and other parts of the world in successful competition with manufacturing firms of other countries possessing highly developed electrical industries.

It is not necessary to refer in detail to the activities of the Board, as these are already well known to our members, and its technical achievements were dealt with very completely in Mr. Johnstone Wright's Presidential Address last year.* For the purpose now in view it is only necessary to give some consideration to certain specific points which must be borne in mind in any future planning of the industry.

At the time of its formation the Weir Committee had the difficult task of devising an organization which could reasonably be expected to achieve the efficiency to be obtained by national planning and control of generation, without unduly interfering with the existing supply authorities who had borne the brunt of the early development of the industry and had incurred large commitments under the protection of statutory rights and privileges. Accordingly, certain important restrictions were placed on the Central Electricity Board's powers. Some of these were relaxed by the 1935 Act, but others that require reconsideration in the light of experience are the following:

(1) The Board is prohibited from owning or operating generating stations save in very exceptional circumstances.

(2) The Board is placed under a statutory obligation that the cost of electricity supplied by it in any year to any owner of a selected station shall not exceed what the cost of independent generation would have been had the Board not been in existence.

(3) Being a new and untried body the Board was, quite naturally, made subject to a considerable measure of technical control by the existing Electricity Commissioners, even on comparatively detailed matters.

On the other hand the Board were given certain powers which may also require reconsideration in the light of experience, of which two may be mentioned:

(4) If the owner of a selected station takes his supply from the Board on the basis of what it would have cost him under independent generation, he obtains no return for the use which the Board may make of his station for providing energy to the Grid.

* *Journal I.E.E.*, 1940, **86**, 1.

(5) The Board is only under obligation to give supply at a single point to any supply authority, however large and however extensive its area, except in so far as the supply authority may have more than one selected station.

I now propose to consider briefly what changes may be desirable in connection with each of these matters.

(1) In very few instances is the output of a generating station completely absorbed by its owner. It is provided and planned for a much wider area and may even, in certain circumstances, be giving supplies 50 to 100 miles away. The location of new generating plant is already planned by the Central Electricity Board, which is also responsible for repaying all operating costs—including capital charges—and for directing the method of operating the plant as regards both output and efficiency. The owner is therefore in the peculiar position of having no responsibility other than providing the capital—on excellent security—and providing the staff for designing and supervising construction and for operation. Hence, in most cases, the owner is only acting as an agent for the Board and gets no direct reward for his work. It may be asked whether, in these circumstances, it would not be better that the Board itself should own and operate all generating plant; if this were likely to result in appreciable economy, it should undoubtedly be done. Such a vast increase in the Board's responsibilities would, however, mean radical change and expansion of staff, would absorb a large amount of the Board's administrative and technical capacity, and would necessitate large regional sub-organizations which would have to be staffed and administered by the personnel of the existing supply authorities. It is therefore probable that any theoretical improvement in economy would be outweighed by the effects of the resulting dislocation and that the balance of advantage is in favour of retaining the present procedure. There are, however, two modifications which are desirable.

(*a*) The Board might reasonably be required to make the owner some payment for the responsibilities imposed upon him. This could be in such a form as to give the owner a direct incentive to economy, both in capital and in operating costs. The procedure would require detailed consideration, but, as a basis, it might be possible to agree in advance the cost of production to be expected, divided into a fixed kilowatt charge and a unit charge, and to pay the owner a proportion of any saving effected during actual operation in either or both of these items.

(*b*) The Board itself should have power to build and operate a station at any point where it was technically desirable to place it, provided the Board could satisfy the Commissioners that the supply authority in whose area the station would be situated had not the experience and personnel to organize an undertaking of such magnitude. Some action in this direction has recently been taken, but only as a war-time measure.

(2) The present arrangement, under which the energy sold by the Board to most of the larger supply authorities is charged on the basis of what it would have cost them to generate their own requirements had the Board not been in existence, is increasingly unsound. It involves estimates, on highly hypothetical grounds, of load forecasts, technical developments and cost, which would be difficult enough if related to recent actual experience, but become almost fantastic as the years pass on. It is a tribute to the staffs of these undertakings and of the Board that, so far, these negotiations, involving very large sums of money, have been found capable of a mutually satisfactory solution; but all parties realize that sooner or later some modified arrangement must be substituted. The present arrangement is, in effect, a cumbersome procedure for settling the minimum reduction in the Grid tariffs necessary for the supply to large undertakings. One logical modification of it which has been suggested would take the form of fixed permanent discounts, on the standard Grid tariffs, of an amount such that if the tariffs (with discounts) were applied to the last few years on which agreements on the charges had been reached the charges would have been the same in total. This would not only provide a direct and simple basis of charge but would also have the advantage of enabling the larger undertakings to share in the general economies produced by the Board's operations when the time arrives for existing Grid tariffs to be reviewed.

(3) Now that the Board is fully established and has all the necessary facilities and data for planning its own growth, it appears unnecessarily cumbersome to retain the procedure under which all extensions have to be the subject of formal schemes prepared by the Commissioners, published by the Board and adopted by them after due opportunity for representations. It should be sufficient for most extensions to the Grid to be carried out under such formal approval by the Commissioners as is normally given to the extensions of authorized undertakers.

(4) An understandable grievance is felt by many of the larger undertakings because they do much to assist the Board's operations but receive no share in the savings these effect. It results from the Board's statutory obligation to base its charges on defined methods of charge, which are generally applicable to certain classes of undertaking. This automatically makes it impossible to divide the savings evenly over all undertakings and, in consequence, some undertakings make very appreciable savings from taking the Board's supply while others make quite small savings or none at all. The Board has, very properly, interpreted its primary duty as being to make cheap electricity as widely available as possible and to extend the Grid to link up with all undertakings throughout the country. This has now been done and a stage is being reached at which the total saving effected will be more than that which it has been necessary to pass on to the smaller undertakings in order to make possible the Board's policy of general availability. When this stage arrives, the larger undertakings have, undoubtedly, a first claim on part of any surplus, in recognition of the assistance which they have given hitherto, without direct financial benefit to themselves, towards the reduction of electricity costs in the country as a whole. The suggestions already referred to under (2) would seem to provide a method of giving effect to this justifiable claim and, in some instances, would be supplemented by the suggestion under (1). Even though any actual benefits might still lie somewhat in the future, the mere fact of ensuring that they would eventually mature would do much to meet the grievance of the larger undertakings and to justify early action in defining the method under which the right to them would be secured in advance.

(5) The original limitation of the Board's obligations to

the provision of one point of supply to each supply authority was intended to prevent supply authorities from using the Grid system to take the place of their own transmission and distribution systems without cost to themselves. On the other hand it is uneconomic for them to have to incur the expense of transmission if it could be done more cheaply by making use of the Grid. The Board has, voluntarily, made arrangements in several instances for such use, but it would clearly conduce to maximum overall economy if the Board were put under an obligation to sub-divide the supply without extra cost and to give it at as many points as a supply authority might require, provided that the Board were entitled to charge to the supply authority all additional capital and operating costs incurred through the provision of the additional points of supply.

would already have necessitated much larger increases in electricity prices.

Apart from monetary saving, national planning of generation has benefited the ultimate consumer by the resulting increased availability of supply. This has also benefited the nation in its war effort, to which must be added the lessened danger from air attack owing to the elimination of the dependence of industrial plants on individual power stations. It should, however, be realized by everyone, including certain Government Departments, that co-ordination of generation cannot substantially increase the total amount of power available throughout the country; it cannot, in short, produce a quart out of a pint pot and has not removed the vital necessity for planning generating-plant extensions in sufficient time to

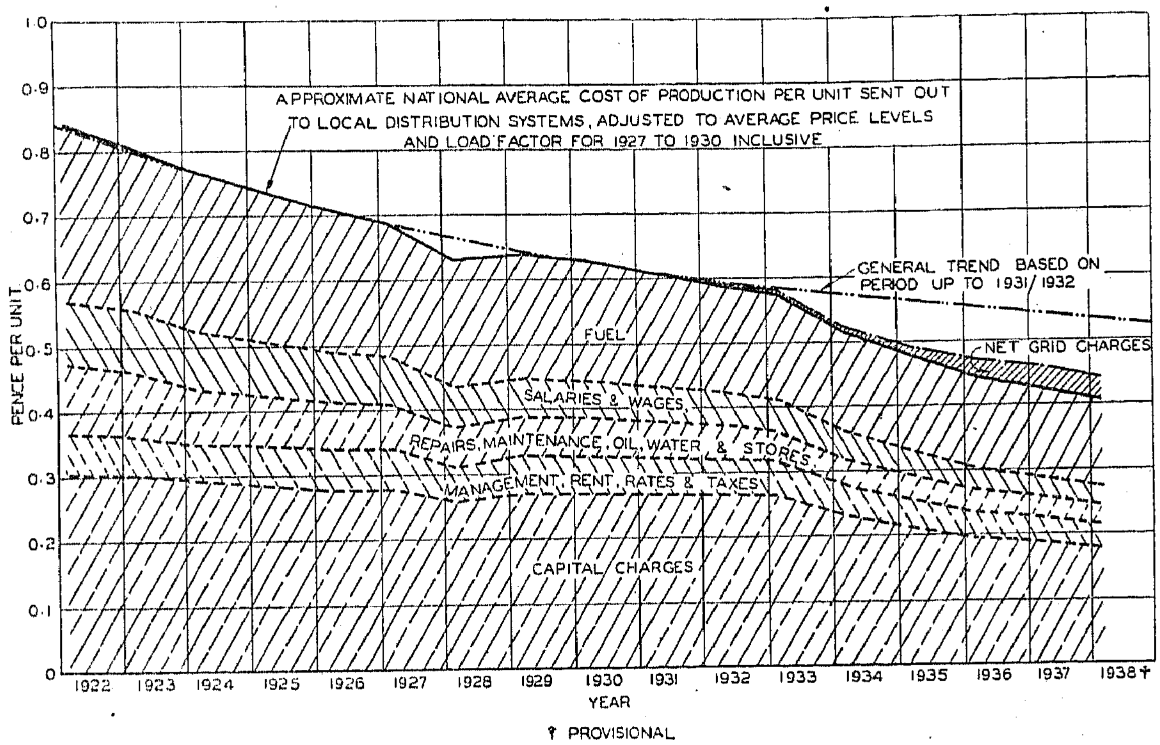


Fig. 1

No doubt other matters would be brought out in any general investigation into the future planning of the generation side of the electricity supply industry, but those mentioned are sufficient to indicate that the time is appropriate for such a review of the situation, even although it is generally admitted that this side of the industry is in good shape and less in need of drastic action than the distribution side.

Fig. 1, reproduced from the Board's Eleventh Annual Report, gives ocular evidence of the substantial economy so far achieved by the national planning of generation. It shows that by 1937–38 the average cost of generating a unit—after taking full account of the capital and other charges of the Grid—had been reduced to seven-eighths of what might have been expected under un-coordinated development. This reduction corresponds to a present annual saving of some £9 million, all of which is being transmitted to the ultimate consumer. Unfortunately its effect is being masked during recent years by the spectacular rise in the price of the chief raw material—coal; a rise due to causes quite outside the control of the electricity supply industry. Had it not been for the co-ordination of generation this increase in the price of coal

deal with increased demand. Generating plants are expensive and complicated, often requiring as much expenditure as the factories they supply and taking longer to construct. Without their outputs of power the factories cannot produce their outputs of munitions.

DISTRIBUTION

When we turn to the distribution side of the industry we see a different picture—the equivalent of a patchwork quilt or a crazy pavement. No substantial measure of national, or even regional, planning has been introduced, and it is here that our most intensive post-war effort will be required. Appreciation that such a problem exists was shown by the appointment of the McGowan Committee in 1935; but even the relatively mild proposals which they made were not implemented by the Government, largely because of the threat of considerable opposition from certain sections of the industry.

The industry exists for the benefit of the ultimate consumer, who is not in the least concerned with its internal structure or with its technical details. He is only interested in being able to purchase his electricity in the form he

requires, wherever he wants it, at the cheapest possible price and on a fair and simple basis. All four of his requirements can be met more efficiently than at present by some degree of national planning, but this must be combined with regional planning, as it is impracticable to contemplate the present 9 million consumers—and the prospective 12 million—being directly dealt with other than through regional bodies in close touch with local conditions.

The national planning side should be the work of the Electricity Commissioners, who must co-ordinate and guide the broad basis of the regional planning. Such planning by the Commissioners is essential if they are to carry out adequately those main duties which have been suggested earlier, and I would urge that they should devote to it an even greater proportion of their energies than they have done hitherto without being discouraged or deterred by difficulties experienced in the past. The need for planning distribution is widely accepted by the industry, although differences of opinion exist as to the actual steps to be taken. The time to make a renewed attempt to arrive at a final and equitable solution in advance of, rather than behind, the inevitable pressure of public opinion is *now*, so that a beginning can be made with the resulting construction work immediately after the war.

I propose to limit consideration of the planning which is required to that section of distribution which is concerned with the supply of current at low voltage for lighting, heating and cooking. I do so not because this is the most important section—although it is of great importance—but because it directly affects the general public, is admittedly in an unsatisfactory position and is the most likely to be the subject of public criticism. Industrial users are, on the whole, reasonably satisfied with the services of the supply authorities and, in any case, developments planned to improve the supply of lighting, heating and cooking will automatically improve the supply of power. It is convenient to consider these developments under the four requirements of the consumer already mentioned.

Type of Current and Voltage of Supply

The enormous growth of portable appliances and the ubiquitous wireless set have given this matter national importance, as has also the increased mobility of the population as the country has become more highly industrialized.

The question of the type of current, over which the giants battled in the youthful years of The Institution, has long been settled in favour of alternating current, though the dust of the conflict is still with us despite the extensive conversions which have been made in recent years. The latest published position (1937–38) is summarized in Table 2, and the comparative figures for 1926–27 indicate the substantial progress over 11 years.

In 1937–38 the number of consumers supplied with alternating current was 8·24 millions, whereas the number supplied with direct current was only 1·12 millions.

It is obviously desirable that the complete elimination of direct current should be achieved as quickly as possible. As a rule it is in the interests of the supply authority to carry out the change-over because it results in greater efficiency of distribution and lower capital cost of meeting future loads. Delay in so doing is usually due either to lack of initiative or to unwillingness to expend capital. Where the latter is due to uncertainty of tenure of company undertakings it is understandable and is a strong reason for eliminating such uncertainty. Subject to this it would not seem unreasonable for alternating current to be made compulsory for domestic consumers after a strictly limited interval, possibly with some provision for grants from a central fund in exceptional instances.

Table 2

	Number of authorities supplying		Millions of units sold for lighting, heating and cooking	
	1937–38	1926–27	1937–38	1926–27
Alternating current alone	298	177	2 247	301
Direct current alone	29	184	16	79
Both alternating current and direct current	267	234	5 085*	1 063*
Total	594	595	7 348	1 443

* These figures cannot be segregated between alternating current and direct current, but the larger proportion is probably alternating current and is increasing.

Almost equally important to the consumer is the question of standardized voltage. The standard is now agreed as 230 volts, and the only difficulty is the cost of standardizing the non-standard systems. Fifteen years ago 50 cycles per sec. was equally accepted as the standard of frequency, but national standardization of frequency seemed to many an impracticable ideal. Sir John Snell thought otherwise and by a bold policy he achieved it. Who would say to-day that his policy was wrong? Criticism is directed, rather, against its increased cost owing to the delay in undertaking it. An equally bold policy is now required in voltage standardization. Our Institution thought so seriously of the matter in 1927 that the Council decided to investigate it. The Committee appointed for this purpose had the full assistance of the Electricity Commissioners, who made a special examination of the position as it then was. On the conclusion of the Committee's work the Council approved the publication of their Report,* which indicated that the cost of standardizing voltages below 220 volts might range from £10 million to £16 million, and above 240 volts would be about 10 % of these amounts. These figures corresponded to between 9½ % and 15 % of the then capital expenditure on distribution. This Report is well worth re-study to-day. Table 3 shows the proportion of the lighting connections at different voltages as this special examination showed it to be in 1926–27, and no more recent figures are available for comparison.

Figures are available, however, of the numbers of undertakings giving a supply at various voltages, and these are shown in Table 4 for 1926–27 and 1937–38.

In considering this Table it is necessary to remember that many undertakings give supplies at different voltages in different parts of their area and are therefore included

* *Journal I.E.E.*, 1930, **68**, p. 516.

more than once. The figures show a substantial advance in standardization, but in the meanwhile the capital expenditure on distribution has been continually rising. In 1926–27 it was £117 million and in 1937–38 £294 million. No doubt a large proportion of the new expenditure has been incurred on standard systems, and therefore the cost of voltage standardization to-day will be a smaller percentage of the present capital expenditure on distribution. Nevertheless it would almost certainly be greater in total than in 1927 and, to this extent, delay has increased the cost as it did in frequency standardization.

Table 3

PERCENTAGE OF CONNECTED LIGHTING LOAD AT VARIOUS VOLTAGES, 1926–27

230 V (standard)	Below 200 V	Range 200–215 V	Range 220–240 V (excluding 230 V)	Above 240 V
22	4	37½	32	4½

In the last year for which statistics are available figures are included for the first time of the number of consumers taking their supply at various voltages. These are given in Table 5, and the trend of these figures in later years will be of great interest. They show that in 1937–38 the total number of consumers supplied at the standard voltage had risen to just over one half.

Some two years ago the Electricity Commissioners decided to take some action on voltage standardization, but owing to various reasons their plans were shelved. They should be taken down from the shelf in sufficient time for the expenditure which would result to be usefully made in the disturbed period which must inevitably accompany the transition of industry to peace conditions. Voltage standardization would then parallel the role which the Grid fulfilled during the world economic crisis. If it is to do so, it must be planned before the transition period arrives. We must not let ourselves be deterred by the magnitude of the expenditure involved; it is quite comparable with that of frequency standardization and of even more direct importance to the public. Arguments against standardization would have more weight if the industry had ceased to expand, but we all have faith in its growth, and further delay can only increase the cost owing to the continuous growth of non-standard systems.

Table 4

NUMBER OF UNDERTAKINGS SUPPLYING AT VARIOUS VOLTAGES

Voltage	1926–27		1937–38	
	A.C.	D.C.	A.C.	D.C.
100	40	6	19	3
200	69	39	59	23
210	15	24	13	15
220	45	91	26	56
230	168	133	437	114
240	73	80	63	46
250	44	18	49	16

How is such standardization to be financed? The simple and direct method of a levy by the Commissioners on the whole industry was adopted for frequency standardization, but it is arguable that the direct gain to the individual undertaking is greater with voltage standardization. It may therefore be felt that only a portion of the cost should be met by a general levy, the remainder being met by the undertaking carrying out the standardization. Special treatment might be thought desirable for those undertakings whose present voltage is above the standard and who therefore stand to gain less. For them the proportion met from the levy might be greater. Standardization should preferably be compulsory, but an alternative would be to make the contribution from the levy progressively less the longer standardization was delayed.

Table 5

CONSUMERS AND SUPPLY VOLTAGES, 1937–38

Voltage	A.C. consumers	D.C. consumers
	Thousands	Thousands
200	1 341	98
205	126	7
210	242	40
220	310	228
230	4 411	379
240	947	274
250	765	79
Other and unaccounted for	99	12
	8 241	1 117

Availability

Few would question that a supply of electricity has become a necessity of modern life; but large sections of the population in rural areas and in the older industrial areas are still unable to obtain a supply, though great progress has undoubtedly been made. The difficulty arises from the length of the educational period which is necessary before the demand in such areas can reach a scale that provides a remunerative return on the capital which has to be invested. But, being a monopolistic service, a public duty devolves on the supply authorities to adopt a sufficiently advanced policy to make their supply available everywhere, even if by so doing there is, temporarily, the equivalent of some subsidizing of the smaller and outlying consumers by the larger and more fortunately situated ones. This has been accepted without question in such fields as postal services, transport, water supply and others, in which it is perhaps more immediately patent that the service is a necessity for all in the interests of all.

Many supply authorities have accepted this public duty willingly, but if the whole population is to receive adequate service, some modification is required in the

existing obligation upon supply authorities to connect consumers. Possibly some limitation might be placed on tariff reductions in developed areas, unless it could be shown that the policy of the supply authority was based on providing general availability at an early date. This, however, might prove difficult to work. A more direct method would be to make general availability compulsory within a limited period, and this could be made to provide further useful construction work during the difficult period to be anticipated after the war. Any supply authority unwilling or incapable of meeting this requirement might then be automatically transferred to a larger adjacent authority which would be under obligation to arrange such absorption on equitable terms approved by the Electricity Commissioners. This would encourage the development of supply areas which each had a fair proportion of undeveloped demand. It is only by the formation of such extensive and financially stable supply areas that the policy of general availability in the public interest can fairly be enforced.

The important question of the capital cost of distribution to farms may require special treatment. After the war, when a diminished income from investments abroad will force us to reduce our traditional import surplus, it may be necessary to subsidize the development of agriculture in an attempt to maintain our standard of living. What better form could such subsidy take than the provision of some part of the capital expenditure necessary to bring the advantages of electric power to our farmers and so permanently to increase their efficiency of production? Once the difficulty of the high capital cost of connection is overcome, the existing rates for supply are already sufficiently favourable to permit of the extensive use of electricity in agriculture.

Price

In considering this we are faced immediately by several of the most disputed problems, the settlement of which has proved very difficult to effect. These are all associated with (*a*) the advantages the consumer is likely to gain from large areas of supply, and (*b*) the form of ownership of the supply undertakings in such areas.

For the consideration of these problems it is desirable to place on record certain fundamental distribution data. Much analysis has been undertaken on this subject, but it is difficult to make entirely satisfactory comparisons because of the complexity of the factors involved and the restricted nature of the statistical information available. I propose therefore to limit the figures given to a minimum and shall deal only with broad trends about which there can, I think, be no dispute.

Fig. 2 shows how the total cost per unit to consumers has varied in recent years. It is evident from this that the proportion attributable to distribution tended to increase until the recent rise in the price of fuel. It is also evident, first, that distribution accounts for the larger share of the total costs, and secondly, that it has shown only a slight tendency to decrease; hence the importance which attaches to any efforts to achieve economies in distribution costs.

(a) Size of Area.

Only to a limited extent can much economy be looked for from technical developments; it must be found mainly through "rationalization." Guidance on this can be obtained by comparing the average relative efficiencies of supply authorities of various sizes as shown by the resulting prices which they are able to charge their consumers. The general effect of size is shown in Table 6.

It would seem a reasonable deduction from these figures that, with equally efficient operation, a supply authority selling less than 20 million units per annum for lighting, heating and cooking cannot achieve the same economy as larger undertakings. It is impossible to prove this for all individual cases, as local conditions and less efficient management occasionally result in exceptionally high costs of distribution in large undertakings; instances can also be quoted of quite small undertakings with sparsely populated areas which, under exceptionally careful management, achieve comparatively low average selling prices. There are, however, no grounds for assuming that electricity supply forms an exception to the universal economic trend and so, within limits, increased size is bound to effect economies in management, staff, purchasing and stores. Experience of this is directly afforded by the results already achieved during the normal growth of existing undertakings, and can also be deduced from the fact that many supply companies have already found it worth while to carry through a considerable degree of consolidation.

The argument for grouping into larger areas, based on increased efficiency and the resulting lower cost of electricity to the consumer, is not the only one. There are less tangible advantages to both existing and future consumers. The larger undertaking is better able to organize sales and to provide facilities for consumers' service. It is also in a better position to raise capital, to adopt long-period plans for increasing the availability of supply, and to carry its proper proportion of temporarily unremunerative consumers.

These general considerations lead to the conclusion that a broad policy of consolidation should be initiated by grouping, under some form of regional management, each supply authority having an output less than that indicated above. Although a few exceptions might have to be made where the area involved would be too unwieldy, such consolidation would result in a decrease in the number of supply authorities from nearly 600 to under 100. The smaller supply authorities which would be thus grouped with larger ones account for 30 % of the total units sold. The resulting expansion of activities would enable the desired economies to be effected without adverse effect on the technical staffs of the smaller concerns and would, in fact, give wider scope for the utilization of proved ability.

One major difficulty in such grouping in the past has arisen because electricity supply areas have always been based on local government boundaries. This came about because the undertakings have been either municipally owned or made subject to eventual purchase by the local authority. This may have seemed the right policy in the early years but the expansion of electricity supply has long rendered it out of date. In fact, the boundaries of the local government areas have themselves become out of date for many purposes, and it seems probable that one of the most important replanning schemes which will have to be put in hand after the war will be the reorganization and consolidation of local

government. Hitherto it has been prevented by local jealousies and the unwillingness of Parliament to interfere in municipal affairs. The experiences of the war, particularly events in the London area, have, however, emphasized the urgent need for action.

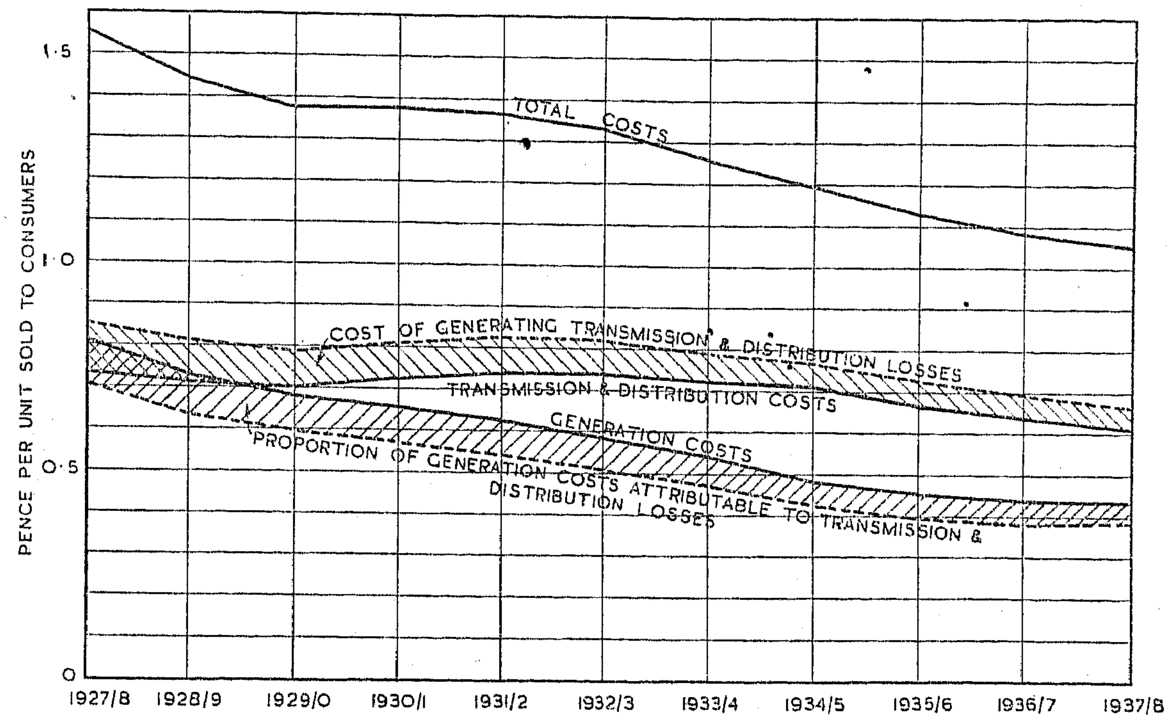


Fig. 2

(b) Type of Ownership.

All proposals for grouping inevitably raise the thorny question of the three possible types of ownership, i.e. municipal, company or some *ad hoc* public body. Rather than attempt to force a rigid universally applied solution and the minimum interference with existing rights. It is not yet possible, in my view, to reach the conclusion that any one type is proved to be ideal, and therefore it would be advantageous to experiment with the different types under new conditions and to test, by statistical comparison over a period of years, the relative efficiencies of the three possible solutions in reducing costs and in giving progressive service to the public. This would put each on its mettle and would be a valuable national experiment from the point of view of planning other forms of industry.

Table 6

RELATIVE EFFICIENCY OF VARYING SIZES OF SUPPLY AUTHORITIES, 1937–38

Grouping of undertakings in accordance with their individual sales of units for lighting, heating and cooking	Number of undertakings in group	Units in group sold for lighting, heating and cooking	Average revenue per unit in group for lighting, heating and cooking	Units in group sold for power	Average revenue per unit in group for power
millions		millions	d.	millions	d.
0–1	158	74·2	3·23	53·7*	1·08*
1–2	78	117·6	2·69	225·4	0·76
2–5	113	361·0	2·25	306·4	0·88
5–10	70	505·9	1·97	766·5	0·70
10–15	44	527·3	1·95	963·5	0·63
15–20	35	611·7	1·70	769·9	0·65
20–30	25	604·5	1·54	1 061·6	0·63
30–50	35	1 332·8	1·55	1 853·1	0·65
Over 50	30	3 213·4	1·56	4 211·1	0·62
Total ..	588	7 348·5	1·69d.	10 211·2	0·65d.

* Excludes 208·7 million units sold for electrochemical purposes by one hydro-electric undertaking which only gives a small public supply.

would it not be best to recognize that each type of ownership has its advantages and disadvantages and that local conditions in one area may favour one type and in another dissimilar area another type? This particularly applies to the relative ease with which grouping can be arranged with the minimum disturbance to the existing organizations

Before approaching the question of the transfer of any actual supply undertaking, it would be necessary to ensure that its consumers would not be adversely affected. If its transfer were to be to a company it would also have to be made clear that this company would be under adequate public control and not hampered in its development by

uncertainty as to its period of tenure and other rights. It is therefore very desirable that any public consideration of grouping should be preceded by an authoritative announcement that it will be dependent on certain basic principles forming an integral part of the plan. The more important of these would seem to be:—

(1) A clear statement that no rigid form of grouping is contemplated and that the only *sine qua non* is that economy will result and that the required unified management will be effectively established, with proper safeguards for the consumer and an incentive to a progressive policy.

(2) An undertaking that all company-owned concerns which are retained will:

(*a*) be granted an extended tenure for a long period only terminable by a notice sufficiently long to avoid restriction of development;

(*b*) be subject to purchase at the end of such period by some form of public authority formed to deal with electricity supply;

(*c*) be purchasable on the basis of actual expenditure properly depreciated;

(*d*) be subject to an approved sliding scale of dividend and to some control of new capital.

(3) A guarantee to the consumers of the smaller undertakings that any grouping scheme will provide that no increases will take place in the tariffs, except such as may be approved by the Electricity Commissioners to cover increases in fuel or other basic costs.

With such safeguards it would not be unreasonable for the Commissioners to be given power to compel grouping. This would be so even where it involved the transfer of a small municipal undertaking to a company, since the economy which would result to the small undertaking by grouping would be greater than any possible difference which might be held to exist between the efficiency of public ownership and private ownership under public control. The whole policy should be one based primarily on the benefit of the consumer rather than on any doctrinaire ideas not directly concerned with this overriding object.

Although compulsory powers of grouping are essential to ensure the carrying-out of the general policy, such compulsion might be held in reserve for a strictly limited period during which voluntary grouping could be encouraged. Such voluntary grouping would have the great advantage of allowing local conditions and wishes to be given due consideration and due, but not undue, weight.

Many of us may think that a bolder scheme of wider regional grouping would be preferable; but in view of past experiences it may be preferable to begin with this more limited scheme and trust to experience of the advantages it will bring in order to justify a further extension at a later date. Such a policy would seem to conform more closely with our national preference for evolution, rather than revolution.

Domestic Tariffs

Electricity is easily measured and a large part of its production is absorbed in capital charges; hence there has been much encouragement to experiment in various forms of tariffs. But sufficient experience has now been obtained to demonstrate that, for simplicity, convenience and promotional qualities, the most suitable form of domestic tariff is that generally known as the two-part tariff or the essentially similar step-block tariff. It is not, as yet, compulsory on every supply authority to offer a two-part tariff, although more than 80% do so. On the other hand, as a relic of early legislation, flat-rate tariffs for different classes of use are obligatory. This position should be reversed; indeed, I would go further and suggest that some form of two-part tariff should be the sole available basis of charge. The difficulty of occasional consumption for lighting only can easily be met by making the fixed charge in the form of a comparatively high price per unit for a certain initial consumption. The actual rates for the fixed and unit charges must necessarily be left to the discretion of the individual supply authorities, subject to some overriding maxima. That for the unit charge should preferably be on a sliding basis correlated with the cost of fuel. Public opinion would, in view of the possibilities of appeal, quickly achieve some reasonable relation between charges in adjoining areas.

Standardization of such a form of tariff for the country is not, however, enough. It must be supplemented regionally by standardization of the basis of the fixed charge. At present many different bases exist, but the two which have become most widespread are rateable value and floor area. Each has its advantages and disadvantages and one may be more suitable in any given region than the other, but it is essential to settle for each region the one to be adopted. An alternative plan, which has its attractions, is for each supply authority in all regions to offer both bases as alternatives, leaving each consumer free to adopt the one which is most favourable to his individual needs.

Two new tariff problems are arising. One is the result of nationally co-ordinated generation, which brings out the importance of limiting the peak loads of undertakings at the time of national peak, whereas the present emphasis is on limiting the peak load whenever it may occur. The other results from the spectacular increase in domestic loads, which is tending to make the domestic load control the peak and is therefore increasing the importance of controlling the incidence of consumers' peak loads and of offering special tariffs for restricted-period supplies. Both these tariff problems are well worthy of consideration by the suggested Planning Council.

I am somewhat concerned that my remarks on electrical planning for Great Britain have proved so lengthy and I trust that the cause may be attributed to the number of things which need to be done and not to prolixity. Before leaving the subject, however, I should like to support the suggestion that when next any general electrical legislation is considered it should be combined with a consolidating Act which would replace the vast number of enactments that have accumulated over nearly 60 years. Lord Birkenhead achieved this for the far more complex system of land laws.

ELECTRICAL PLANNING IN THE EMPIRE

I am not competent to deal with possible schemes for post-war planning in all these various parts of the world, but there can be no doubt that the discussion of our home problems may prove of assistance to our members overseas in dealing with corresponding problems elsewhere, although

they usually have to deal with much wider and more sparsely populated areas. Conversely, it is certain that electrical planning already carried out overseas will have produced lessons and experience from which this country may usefully learn. It is therefore not out of place if I conclude with a brief survey of its trend prior to the war under the same three heads of national supervision, generation and distribution.

National Supervision

Because of the lateness of their development and the smaller scale of their industry, other parts of the Empire have not had to deal with such complicated legislation or such chaotic organization as existed in Britain after the last war. National supervision has therefore been much easier to apply. Where central or national generating authorities have been set up, the functions of supervision have usually been carried out by them—as in Eire, Victoria and most of the Canadian provinces.

South Africa, Quebec and Southern Rhodesia have followed more closely the example of Britain in establishing a separate supervising authority, but on a narrower basis and with little control of municipalities. Similar bodies, with varying powers and functions, also exist in British India, New South Wales, Queensland and Kenya, but elsewhere in the Empire supervision is usually exercised directly through Government Departments, which are in many cases primarily devoted to some allied activity such as local government or public works.

Generation

The variety of conditions under which electricity is generated is so great as almost to defy classification, but there has been a strong trend, particularly in the Dominions, towards some form of monopoly. For the most part this has resulted from the establishment of independent Government Commissions, of which Victoria, Ontario, Eire and South Africa are the best-known examples, though there are smaller organizations such as the one in Trinidad.

Frequently a Government Department has built and operated generating stations, gradually becoming a monopolist in the field of generation and bulk transmission. This has happened in such varied places as New Zealand, Western Australia, some Indian States, Malta and the Gold Coast.

Over the rest of the Empire private and municipal enterprise dominate the field, though the trend towards monopoly is still clear. New South Wales has built up the large municipal undertaking of the Sydney County Council, which controls about three-quarters of the supply in that State. In Queensland, Palestine and Kenya there is a definite policy of concentrating generation into the hands of large private companies, whose activities are carefully regulated in accordance with public policy. There are also large areas, particularly in the more backward Colonies, where licences are granted to municipalities and private companies, very much as they were in the early days of English development.

Distribution

The attitude of monopolist generating authorities towards distribution to the consumer varies from vigorous participation, as in Eire, to restricted activity outside existing developed areas, as in Victoria and South Africa, and even to a complete refusal to participate. In general there is not a great tendency for the generating authorities to organize retail distribution, the stronger tendency being to encourage municipal undertakings. New Zealand, realizing that its ordinary local authority was too small a unit for efficient distribution, has set up Electric Power Boards with rating and other special local authority privileges, and these Boards cover the areas of several local districts.

Attempts to improve retail distribution have usually included the encouragement of rural electrification. This has taken many forms and has usually involved some kind of subsidy, either from the Government or from urban consumers. For example, a practice which is growing in Canada is for the Government to give active encouragement by providing half of the capital for rural distribution networks. An example of the other method is provided by the big private undertaking in Brisbane, which is not allowed to charge prices in the surrounding rural areas more than 10% above prices in the urban area, any resulting loss on the rural supplies thus being made good by the urban consumer.

CONCLUSION

In concluding an Address which has ranged over a wide field may I express the hope that the attention I have given in the later part to the practical problems of the future planning of electricity supply will not have unduly diverted the attention of my audience from the more general questions with which I began. Any practical planning problems may prove insuperably difficult unless these fundamental problems are fully appreciated and their lessons properly applied. I feel convinced that failure to do this is the greatest danger that lies before us all in the difficult times ahead. It is a danger specially to be guarded against by our younger members who must, as years go on, carry more and more of the responsibilities of our profession and whose lives will, to a great extent, coincide with the years of opportunity for the reconstruction of society and the building of a better world than they have inherited. These words of Sir Philip Sydney should be their inspiration:

> "It is the temper of the highest hearts to strive most upwards when they are most burdened."

METER AND INSTRUMENT SECTION: CHAIRMAN'S ADDRESS

By C. W. MARSHALL, B.Sc., Member.*

INTRODUCTION

I wish to thank the members of this Section for electing me to be their Chairman for the current session, and to assure them that I am fully appreciative of the honour they have thus conferred upon me.

The best which I can provide as an Inaugural Address is a summary of some interesting and important factors involved in the construction and operation of the British Grid system, having a direct bearing on matters which concern the Meter and Instrument Section.

The greater part of this Address deals with peace conditions, the Grid having been designed and constructed on the assumption that such conditions would prevail throughout its existence. The situation created by the war is only touched on in this Address; but after the war there will be material for papers of unique interest on technical experiences now being encountered, since modern warfare has provided us, in the course of a few months, with the electrical experience of many normal lifetimes.

I have arranged my material in sections dealing with energy, power and reactive-component measurements; indicating instruments in relation to economy and reliability of power-system operation; discriminative protective equipment; and fundamental electrical measurements in relation to power-system operation and maintenance.

ENERGY, POWER AND REACTIVE-COMPONENT MEASUREMENTS

All energy, power and cognate reactive-component measurements on the Grid system are made by metering equipments installed in accordance with the provisions of the Electricity Supply Act, 1926. They measure all the power and energy generated in selected stations supplying the Grid and used by authorized undertakings to give supplies to the individual users of electricity throughout the part of Great Britain in which the Central Electricity Board operates.

The power supply to the Grid at peak load in 1939 was 7 000 MW, and the energy generated during that year was 21 000 million kWh. Approximate measurements of the associated reactive components were also made to determine the power factors required in assessing the supply costs under the 1926 Act.

The Grid metering scheme was described by me in a lecture to this Section on the 2nd May, 1930. Supplementary technical information was supplied by Mr. J. Henderson in a paper entitled "Grid Metering"† in 1934. I will therefore confine my present observations to the functioning of the metering equipment under commercial conditions.

Polyphase kWh meters had been developed to a high degree of mechanical and electrical perfection before the date when the Grid metering was being considered, but in view of the evident commercial importance of high accuracy and reliability in relation to the Grid measurements the principal British meter manufacturers revised their meter designs in order to increase accuracy. The success of their actions to this end may be judged from the fact that, after 10 years' service, the Grid meters continue to function with such accuracy and reliability that their registrations are almost invariably accepted without question by every authorized undertaking in Great Britain.

The ultimate tribunal of reference in matters relating to meter accuracy is the National Physical Laboratory. So far, there has been no call by outside parties for independent checks on the Grid meters, but the Board has taken the precaution of submitting sample meters of all types to the N.P.L. for re-test after long periods of service; with the result that these meters have been found to be registering well within the originally prescribed error limits. According to the N.P.L. the maximum absolute error in registration of the sample meters, within the working range of load and power factor, is of the order of $+0 \cdot 5\%$. These basic measuring units—the kWh meters—have therefore proved to be capable of working with complete reliability and extraordinary accuracy for a period of over a decade. Their effective life under peacetime conditions would be far in excess of statutory requirements.

The integrating meters form the initiating elements of a chain of units which finally provide the Board's accountants with data from which to prepare their statements of supply costs. The remaining major elements of this chain are the summating system, the long-scale maximum-demand indicators, and the maximum-demand printometers. They were all specially developed to meet the requirements of the 1926 Act. There is no independent tribunal to pass judgment on them, but they have been subjected to the continuous critical examination of the metering engineers of the authorized undertakings, who are unlikely to have missed any technical weakness in the measuring system. The equipments have survived that examination with credit. There is no technical reason why these components, which incidentally are subjected to more onerous stress conditions than the integrating meters, should not continue to perform their destined functions for the statutory life period and beyond it; but, apart from the everyday hazards to which all persons and equipments are now being subjected, there are indications that the metering system may be modified, or even replaced, for reasons other than technical obsolescence.

Although the potential sequel is to some extent speculative, I will draw attention to it because of its general interest. Those who have to deal with electricity-supply accountancy in general, and with selected-station costs in particular, will recognize that the correlation and analysis

* Central Electricity Board.
† *Journal I.E.E.*, 1934, 75, p. 185.

of meter readings is an involved and tedious process. This fact was recognized at the beginning of the Grid construction, but the metering system chosen was the best which could then be put into practice. The most promising of several alternatives which were initially considered was to use the integrating meters to perforate cards from which the requisite records could subsequently be compiled by means of mechanical accounting machines. Within recent years this scheme has been revived from the accountancy end, and the perforated-card process of translating electrical records into costs is being carried out in calculating machines. The next step in development will probably be to revive and realize the scheme of perforating the cards directly on the basic meters. This speculation perforce assumes adherence to the strict conditions of the 1926 Act, but, since it is hardly possible to complicate these conditions, any amendments will probably be in the direction of simplification, so that the perforated-card method of meter recording will be capable of fulfilling all future requirements in respect of electricity-supply costs.

The possibility of mechanization of meter reading clearly extends far beyond the narrow limits of Grid metering, and is potentially applicable to all meters. In my opinion, it represents a most interesting line of development which should be considered in detail by this Section when peace returns.

INDICATING INSTRUMENTS AND POWER-SYSTEM OPERATION

Passing on to the instruments which are used for routine operating purposes, I am pleased to report that the classes of indicating equipments which were in everyday use on British supply systems, and which were adopted for the Grid, have served their purpose in an entirely satisfactory manner. With these instruments, as with integrating meters, there is little scope for technical advance. It is, however, possible to effect considerable improvement in regard to the rationalizing of indicating-instrument equipments; e.g. conservatism has perpetuated the use of large instrument control boards in spite of the fact that the advantages of miniature instruments have already been demonstrated in a few power stations. The aircraft and motor-car industries have demonstrated on a vast scale that power plants can be conveniently and effectively controlled from miniature instrument boards, with which almost everyone is familiar. There should therefore be a departure from conventional power-station switchboards and a trend towards the much more elegant, compact and economical arrangements used in air and road transport working. In this connection I would remind readers of the fact that integrating meters in this country have progressed from the heavy, clumsy, cast-iron-cased variety, which were formerly demanded by most supply engineers, to the light, modern, pressed-steel-case types. Manufacturers have made similar advances in the design of indicating instruments. It seems reasonable to expect the electricity-supply industry to keep pace with the advances.

A minor detail of electrical and other instrument practice which merits consideration in the interests of economy is the scale form. Adoption of decimal or percentage scales would eliminate the need for differentiating between voltmeters, ammeters and wattmeters, and would simplify considerably the procedure for using instruments in conjunction with current and voltage transformers.

Although all classes of instruments have been improved in detail during the period now under review, the type which has come into greatest prominence in Grid operation is the frequency meter. The operating engineers have been striving continuously to improve accuracy of electrical timekeeping, as a subsidiary indication of thermal efficiency. This involves accurate maintenance of frequency at the standard value of 50 c./s. It is essential for this purpose to have highly sensitive and accurate frequency indicators so as to enable the operating engineers to use the generating plant to its best advantage. Such indicating frequency meters have been produced and, I hope, will be described to The Institution hereafter.

I have so far confined my remarks to those instruments which are adjacent to the apparatus controlled, as were most instruments before the Grid was put into service. The correlation of control and operation of large numbers of power-station and switching-station units in common control rooms, which are distant from most of the controlled stations, has brought about the production of many instruments of a novel type. (General particulars of the Grid control stations and their equipment can be found in the paper by Mr. J. D. Peattie entitled "Control Rooms and Control Equipment of the Grid System."*)

The detail of control which, I believe, will be of most interest to members of this Section is that of transmission to the control centres of readings of instruments, particularly wattmeters, by means of pilot circuits. The control engineers must have continuous indications of the loadings on generating stations and certain key circuits in order to operate the power system with maximum economy and security. The pilot circuits between the distant stations and the control centre are the channels provided by the Post Office for the general telecommunication work used in controlling the Grid. They therefore vary from short 2-wire metallic circuits to phantom circuits up to about 50 miles long. Initiating and receiving equipments have been developed to meet all these diverse requirements in the pilot circuits, and the control engineer is thus provided with the information he requires regarding the loads on key stations and circuits. In this development telecommunication engineers have been of exceptional service to power engineers.

DISCRIMINATIVE PROTECTIVE EQUIPMENT

The instruments which have so far been referred to are useful mainly under normal working conditions in which no sudden loading changes take place. They serve a useful purpose during a great proportion of the operating time. They cannot, however, record the extremely rapid transient phenomena which occur during fault periods. It is under these transient conditions that many of the most difficult technical problems arise. The first of these problems is that of disconnecting a faulty section of a transmission system without disturbing neighbouring sound sections. This problem had been satisfactorily solved, prior to the decision to construct the Grid, for the special cases in which pilot conductors could be provided between the termini of the apparatus to be protected. The use of

* *Journal I.E.E.*, 1937, **81**, p. 607.

pilot wires on all sections of the Grid for the sole purpose of rapid selective clearance of power-line faults was, however, judged to be entirely uneconomic. It was therefore decided to restrict the use of pilots to short sections of power line where they would be provided at relatively low cost—as, for example, in conjunction with underground-cable sections. In a few instances pilots hired from the G.P.O. were used for the protection of power lines. In the majority of cases, however, pilotless protection had to be used, and in these cases it was necessary to use protective gear of a type previously unknown in British practice. This class of protective gear was designed with a view to obtaining selective clearance of faulty sections of line within periods of time comparable with those required for clearance by balanced pilot protective-gear. The heterogeneous arrangement whereby short sections of the Grid lines and of transformers and switchgear have balanced pilot-wire protection, and longer sections have so-called distance protection, has given service the value of which may be assessed from the fact that 90% of all faults are cleared discriminatively. This matter of efficiency of fault clearance is of the highest importance. If the ratio of kWh delivered to consumers to kWh delivered to consumers plus kWh lost due to supplies being cut off, were used as a measure of efficiency, the figure for this country would be of the order of 99·99%. This figure could be used in practice with some justification, but the effect would be to induce premature satisfaction with protective-gear development. Concentration on the 10% of incorrect clearances of circuits is more useful as it indicates wherein existing protective systems and gear are defective. To improve the efficiency above the 90% figure will involve much expenditure on equipment and personnel, which will be incurred as and when the demand for electricity justifies it.

The degree of success in discriminative clearance of faults is, of course, dependent on the action of power apparatus, particularly circuit-breakers, as well as on the protective system; but consideration of the phenomena of circuit-breaking does not come within the scope of this Section. It will therefore suffice here to mention the fact that at the beginning of the construction of the Grid, and for many years thereafter, the action of oil circuit-breakers was so variable in respect of arcing times that no relay system could ensure a high degree of discrimination in clearing certain types of fault.

Modern circuit-breakers are now greatly improved in respect of speed and consistency of operation under fault conditions. Relay engineers have therefore had an important and troublesome variable eliminated from their problem of securing accurate discriminative clearance of faults. The pilotless systems of protection which were adopted on economic grounds, in conjunction with modern circuit-breakers, can therefore give a closer approximation to the performance of the simpler but more expensive current-balance systems. Pilotless protective schemes are, nevertheless, inherently incapable of giving the highest degree of discriminative action and, as the demand for reliable electrical supply develops, there should be a reversion to the unit system of protection. This reversion process is in progress, and interlock protection using carrier-current control with the power lines themselves as pilots is now being applied to many new high-power transmission lines. Carrier-current protective gear involves co-operation between power engineers (who are responsible for the fault-diagnosing relays) and radio engineers (who are responsible for the high-frequency carrier-current apparatus). Protective equipment is as important to power-supply services as is signalling to railway services. The result is that a new class of specialists is beginning to be formed who concern themselves with such matters as calculation of fault currents and the design and application of power relays and of carrier-current equipment. The mental qualities required for such work are of an exceptionally high order, and the degree of competence is subjected to absolute test by the manner in which the equipment for which the specialists are responsible functions to maintain continuity of electricity supply. In peace time, protective equipments were called upon to function at very infrequent intervals, but war has made protective action commonplace and has brought into clear relief the excellent work done by the field staff in keeping the protective gear ready for all emergencies.

To improve on the figure of 90% which has already been attained for discriminative clearance of faults, it would be necessary to increase capital expenditure by an excessive amount if evolution were to proceed on conventional lines. It appears probable, however, that higher efficiency will be obtainable by utilizing quantitative records of fault phenomena to trace reasons for non-discriminative action during faults. All sections of the Grid are gradually being equipped with automatic recording apparatus whereby the necessity of synthesizing fault phenomena from relay operations and calculations will be eliminated. Such records are, in addition, valuable as a means of locating faults and so assisting in everyday operation by making it possible for repair squads to proceed directly to places where they have to work, without preliminary location by patrols. In this country we have to some extent lagged behind other countries, particularly America, in the development of the necessary instruments for the purposes thus described, but we are now rapidly producing instruments in line with our own needs and resources. I anticipate that the future will see the establishment of many analysing centres where all abnormalities of the national electricity supply will be investigated. Such centres would be analogous to meteorological observatories and would have, in addition to the work of recording transient electrical phenomena associated with faults, that of analysing them and indicating how system operation might be improved.

FUNDAMENTAL ELECTRICAL MEASUREMENTS

Having considered the transients ranging in duration from a few cycles to a few seconds caused by insulation failure or instability of loading, we pass on to the subject of short-duration transients lasting at most for a few milliseconds and arising from lightning or switching of power circuits. In peace time, lightning is the most prevalent cause of failure of power-transmission equipment. Its effects have been known qualitatively to operating and maintenance engineers for many years, and, as the use of overhead-line transmission has extended, the effects of lightning have increased proportionately. It has been apparent that lightning troubles, although infrequent and,

in relation to war conditions, insignificant, are the most insidious of those troubles encountered on power systems. It has, nevertheless, been possible to devise measuring technique for investigating lightning phenomena. The cathode-ray oscillograph, which has largely been popularized by members of this Section, has been the most valuable instrument for examining the nature of lightning and its effects on insulation.

While much work has yet to be done to collect adequate data regarding natural lightning, the information which has already been obtained about it is in itself sufficient to justify our developing lightning protective devices.

The production, measurement and control of impulse-voltage waves for testing the ability of electrical apparatus to withstand lightning stresses is now in advance of the design of lightning protective equipment—in Great Britain, at least. The transformer engineer, on the basis of information provided by such instruments as the recurrent-surge oscillograph, is so arranging the insulation of transformer windings as to provide the maximum degree of immunity from insulation breakdown under impulse-voltage stresses. At the same time the supply engineer is learning how to arrange his apparatus in such a way that the possibility of failure of transformers due to direct lightning stroke can be practically precluded. It has, however, to be kept in mind that even with the present standard of design and construction of apparatus and of transforming and switching stations, a remarkably high degree of success in providing cheap and reliable supplies of electricity has been reached. There is therefore an understandable tendency on the part of many responsible engineers to accept the situation as satisfactory for the present, and to leave the work of securing further improvement to a few experts. These experts are now being called upon to produce lightning protective devices in accordance with the economical and technical needs of the case. There are good reasons to anticipate that such devices will soon be available for commercial use.

In conclusion, I wish to make some observations on the slowly-acting phenomena associated with electricity supply which are liable to be forgotten in the stress of war. I refer particularly to deterioration of insulation. The increase of specific electric stress on insulation due to increase of system voltage has revealed certain weaknesses in insulating materials. It is not commercially practicable, or even possible, to improve the materials to such an extent that there will be no such weakness. The remedy therefore lies in finding means of eliminating the weak elements before they fail completely. Even porcelain, which in low-voltage applications seemed to be, for all practical purposes, everlasting, has proved to be somewhat vulnerable to the combination of mechanical, thermal and electric stresses to which it is subjected in high-voltage transmission-line use. The application of sound fundamental principles of measurement by determining the voltage gradient along chains of line insulators or sections of post insulators has made it easy to locate faulty units. These can then be replaced and the factor of safety restored to its orginal value at comparatively small cost. In fibrous insulation the problem of locating a faulty part is more difficult. A tentative solution has been found by developing means whereby the dielectric losses of such insulation can be conveniently measured. The measuring equipment takes the form of either specially sensitive indicating wattmeters or the Schering bridge. By comparison with figures obtained on new insulation and at intervals of normal service it is possible for experienced technicians to distinguish when insulation is deteriorating and to tell when it must be removed if breakdown in service is to be avoided. In this field of what may be termed "insulation pathology" there is much scope for members of this Section who have a bent towards precise measurement. I hope that it will not be long before all electrical-plant maintenance is based on quantitative measurements of critical characteristics rather than on arbitrary intervals of time established for the most part by expediency.

I have indicated briefly how experts in electrical measurements—mainly members of the Meter and Instrument Section of The Institution—have helped to establish the Grid construction and operation on a sound foundation; and how they have produced meters, protective gear and fault-diagnosing apparatus which have assisted in bringing about the present standard of reliability and efficiency of British electricity supply. In all these branches there is still much difficult technical work to do, which will keep the members of this Section occupied and interested as long as electricity supply persists.

WIRELESS SECTION: CHAIRMAN'S ADDRESS

By W. J. PICKEN, Member.*

I wish to express my warmest appreciation of the honour you have bestowed in allowing me to serve as your Chairman during this Session. I regret exceedingly that the present state of world affairs renders necessary a departure from our normal procedure and a curtailment of the very pleasant social activities associated with our Meetings.

C. E. Rickard, in his Chairman's Address to the Wireless Section in 1930,† stated that the membership of the Section at that time was 529. We are now in the opening months of the third decade of our existence and our membership is 1 133. The increase has been steady and continuous, and bearing in mind the industrial depression which darkened the first half of the intervening period we need not consider it unsatisfactory. We are a Section of The Institution representing young, vigorous and rapidly growing industries, and we wish to be truly representative of the many-sided activities of those industries, especially those of communication engineering to-day.

These Addresses sometimes sound a more personal note than the serious technical papers that occupy your attention during the remainder of the Session. The matter which forms the subject of this talk is one with which I have been intimately concerned for over a quarter of a century, a period which has coincided almost exactly with the development of wireless transmitting valves as we know them to-day. I hope you will accept these reasons as sufficient excuse for the personal references which occur in this necessarily brief survey.

Although it had been known for many years that in the vicinity of hot metals air becomes a conductor of electricity, it can be said that the scientific study of the conduction of electricity through gases has been carried out within the memory of living man.

Two years after the founding of this Institution, Guthrie, in 1873, demonstrated that a negatively charged electroscope was discharged when a metal ball heated to a dull red was brought near it. With the metal ball at a higher temperature an electroscope either positively or negatively charged became discharged when brought near to the heated metal.

In the eighties of last century Elster and Geitel studied the conductivity of gases near heated bodies and noted the effects of altering the temperature of the metal with different gases at varying reduced pressures of the gases.

In 1883 Edison had some trouble with carbon-filament electric incandescent lamps. Hot spots due to diminished cross-section of certain parts of the filament caused premature burn-out and blackening of the bulb through carbon particles from the filament, projected in straight lines from the hot spots, adhering to the glass bulb. In his investigations of this Edison had a plate fitted in the lamp between the legs of the filament. He found that if the plate was connected to the positive end of the filament a current flowed in the plate circuit, but that no current flowed when it was connected to the negative end of the filament.

The first paper printed in the first volume of the *Transactions* of the American Institute of Electrical Engineers was read before that Institute in Philadelphia in October, 1884, by Edwin J. Houston, on "Notes on Phenomena in Incandescent Lamps." In order to convey an impression of the interest aroused by what is now known as the Edison effect, the following extracts are made from Prof. Houston's remarks: "I have not prepared a paper but merely wish to call your attention to a matter which, I suppose, you have all seen and puzzled over. Indeed, I wish to bring it before the society for the purpose of having you puzzle over it. I refer to the peculiar high-vacuum phenomena observed by Mr. Edison in some of his incandescent lamps. . . . The question is, what is the origin of this current? How is it produced? Since we have within the globe nearly a complete vacuum, we cannot conceive the current as flowing across the vacuous space, as this is not in accordance with our preconceived ideas connected with high vacua."

At about this time J. A. Fleming started research and experiments, which were continued over several years, with a view to answering these and other questions concerning the Edison effect. Some of the results of his investigations were described in the *Proceedings* of the Physical Society in 1883 and 1885, and of the Royal Society in 1889, and demonstrations were given before the Royal Institution in a Friday evening discourse in 1890.

J. J. Thomson in 1897 showed that the conduction of electricity through gases is by means of minute unitary charges of negative electricity emitted by the hot filament.

As C. C. Paterson lucidly puts it in the Tenth Faraday Lecture,† when speaking of the free state of electricity, "It all started with the discovery by Sir Joseph Thomson in 1897 of the electron, that minute ultimate constituent, which is to electricity in the mass what the grain of sand is to the whole sea shore. After Thomson, electricity had no longer to be studied and thought of in the mass. It was made up of myriads of separate electrons whose characteristics could be studied. The discovery by this great Cambridge physicist was hardly noticed by engineers until well into the present century."

At the beginning of the present century O. W. Richardson, working along both theoretical and experimental lines, advanced the theory that the electron emission is a property of the conductor, and is not dependent on the surrounding gas. He derived mathematical laws for the electron emission as dependent upon temperature, the accuracy of which has been well established. Richardson was the first man to use the term "thermion," from which is de-

* Marconi's Wireless Telegraph Company, Ltd.
† *Journal I.E.E.*, 1931, 69, p. 11.

† *Journal I.E.E.*, 1934, 75, p. 447.

rived the term in common use to-day, "thermionic current."

Owen, in the *Philosophical Magazine* for 1904, showed that the filament of a Nernst lamp when heated emitted free electrons.

Wehnelt in 1904 published the results of his experiments, which showed that the platinum cathodes with a lime coating gave much greater emission of free electrons than did the platinum filament without the lime coating.

In 1904 Fleming patented the "oscillation valve," a 2-electrode valve with a hot carbon filament, as a detector of wireless-telegraph signals. This valve, which has come to be known as the Fleming valve, proved a very valuable instrument for that purpose, and is the prototype of all thermionic valves. About 1907, De Forest introduced a third electrode into a valve, which he called the audion. For a few years subsequent to this there was a partial eclipse of the Fleming valve owing to the discovery and use of various kinds of crystals as detectors of wireless signals. These were more sensitive than the Fleming valve, and were simpler in that they did not require a battery to heat the filament, had a longer life and were generally cheaper to use. It would appear that the De Forest audion also languished, its enormous potential power as an amplifying device either undiscovered, or not appreciated and unapplied.

Lieben and Reisz in 1911 produced a 3-electrode valve as different from the audion as could well be imagined. The Lieben valve, as it was commonly called, had a Wehnelt cathode about 1 m. in length composed of platinum strip with lime coating and requiring about 4·5 amperes at 30 volts to heat it. The anode was in the form of an open spiral of wire at the opposite end of the bulb from the filament. The control electrode, for which the term "grid" is really a misnomer, was in the form of a metallic disc effectively dividing the bulb into two parts. This electrode had a number of round holes drilled through it to permit the passage of electrons. There was a certain amount of mercury vapour present in the bulb, which could be replenished by applying heat to a pellet of mercury amalgam in a side tube. The filament voltage was high enough to maintain ionization in that part of the bulb in which the filament was mounted. The anode voltage likewise gave rise to visible ionization on the anode side of the grid. When the valve was functioning properly there was a dark space on both sides of the grid separating the two clouds of blue glow. If the anode voltage was too high or the mercury vapour pressure too great the blue glow embraced the grid, and the valve ceased to function as an amplifier.

The Lieben valve had some of the attributes of the modern gas-filled relay or thyratron, but was capable of following the variations of grid voltage imposed by the incoming wireless signals with a constant d.c. anode voltage.

Using this type of valve, Meissner in 1913 produced high-frequency oscillations with inductive reaction between the anode and grid circuits, and transmitted speech by wireless telephony over a distance of 35 km. This, I believe, can be taken as the starting point of the use of the thermionic valve as a generator of high-frequency oscillations for continuous-wave wireless transmitters.

Lieben valves cost us about £30 each, in which respect as well as in physical dimensions they bore a resemblance to the modern medium-power transmitting valves. I used Lieben valves for the reception of transatlantic wireless-telegraph messages at Letterfrack, Connemara, in 1913.

Using these valves, Franklin and Round and others were able to carry out work which resulted in, amongst other things, the discovery of negative resistance associated with reaction, which was used so greatly in the early days of broadcast reception, and of the self-heterodyne rectifier for the reception of continuous-wave telegraph signals.

At this time Langmuir was working on the production of better vacua in thermionic devices, the far-reaching results of which were given in a paper read in April, 1915, before the Institute of Radio Engineers, New York, on "The Pure Electron Discharge and its Application in Radio Telegraphy and Telephony."* This very notable advance in the art was coupled with the production of a transmitting valve capable of dissipating 250 W at its anode and of converting 1 kW to high-frequency energy utilizing pure electron discharge.

In 1913 Coolidge made an X-ray tube capable of working at 200 000 volts, and the rectifying valves for providing this voltage using hot cathodes and pure electron discharge.

I did not hear anything about "hard valves," as valves using pure electron discharge are commonly called, until the autumn of 1914. At that time I was in the U.S.A. and was helping my friend Roy A. Weagant on transatlantic reception. Nauen station, near Berlin, had changed from spark to continuous wave at about the beginning of the first world war, and reception of continuous waves by means of audion-type valves was a tricky and uncertain operation. I remember the relief we felt when Weagant procured some hard audion types of valves, pumped, I believe, at Columbia University. In 1914 I brought some of these hard valves home with me to England, where they were received with great interest.

Amongst the soft receiving valves in use in this country at that time was the Round type C, with which a very high degree of magnification could be obtained. As stated by Round in his paper on "Direction and Position Finding,"† read before The Institution in 1920, "It was probably fortunate in the first year of our work that we used the soft valves because no hard valve has been constructed (in 1920) which can compare with these 'C' type tubes as high-frequency magnifiers."

The Round type T transmitting valve was produced in 1913, and early in 1914 Round and Tremellen used it to transmit speech by wireless telephony over a distance of 70 km. Although usually classed as a soft valve, it was actually exhausted as thoroughly as its construction and the vacuum technique available permitted. The pellet at its extremity was inherited from its prototype, the soft receiving valve, and was an unnecessary appendage.

Among the commercial wireless companies in this country the war forced the development of receiving valves and hindered the development of transmitting valves, further advances in which were not forthcoming until nearer the end of the war. There is no hard-and-fast division between receiving and transmitting valves. Frequently the former are used in small-power transmitters. Small hard receiving valves of the V.24 type were used at this period in small portable transmitters, with which continuous-wave tele-

* *Proceedings of the Institute of Radio Engineers*, 1915, 3, p. 261.
† *Journal I.E.E.*, 1920, 58, p. 224.

graph signals were sent over distances exceeding 100 miles.

The advent of the high-vacuum technique and the hard valve coincided with an almost complete change from platinum-iridium filaments coated with alkaline-earth oxides to the tungsten type of filament. Electric-lamp manufacturers had come to use tungsten with an admixture of a small amount of thoria to give greater strength to the filaments of electric lamps, and as most of these companies also manufactured valves, the same type of wire was used in both receiving and transmitting valves.

In his paper* read before The Institution in 1920 Gossling describes the "Development of Thermionic Valves for Naval Uses," and takes the story of the development of transmitting valves a stage farther. Type T1 was developed in 1916 and was in production early in 1917. Apart from the method of anchoring the filament spring on the anode foot tube, it conforms very well to present-day design of valves of its class and is still used in considerable numbers.

Gossling also describes the type T4A, a larger valve of rather later design whose tested anode dissipation is 400 W; and which is capable of converting 1 kW of power to high frequency in a circuit of good efficiency. These valves had filaments of tungsten with an admixture of thoria, and the high emission sometimes obtained from such filaments in these valves was noted by Gossling.

Transmitting valve MT1 was the first of a long series developed for the Marconi Company by the M.O. Valve Co. With valves of this type Ditcham in 1919 transmitted speech by wireless telephony from the west coast of Ireland to me at Louisburg, Cape Breton Island, Nova Scotia.

Type MT2 was one of the biggest transmitting valves equipped with nickel electrodes; the tested anode loss was 600 W. Before the advent of higher-powered units a considerable amount of useful high-power transmitting was done by means of these smaller units used in parallel. As an example, at Carnarvon 48 type MT2 valves were operated in parallel with an input power of 180 kW, on transatlantic traffic in the early twenties of this century. This transmitter continued in operation for several years and gave satisfactory results. The conversion efficiency obtained from such an arrangement, or shall we say array, of valves was very high indeed. At Carnarvon a large number of very careful readings gave an efficiency for the last stage (not including the drive unit) of nearly 100 %. We were a little disturbed by this high efficiency, but at a later date when these MT2 valves were replaced by a smaller number of higher-power water-cooled valves an efficiency of the order of 80 % was obtained under otherwise similar conditions.

Over a period of some years, glass transmitting valves evolved gradually into higher-powered units. Larger and larger glass bulbs were used, until a physical limit was reached beyond which they could not conveniently be blown or handled by man unaided by machinery. Various means were employed to increase the permissible loading of the anodes. Nickel anodes were roughened by means of sand blast and acid etching, and blackened by oxidizing or carbonizing. Corrugations were also used to increase the radiating surface. Later still, anodes cut from solid graphite came into use for certain types.

* *Journal I.E.E.*, 1920, 58, p. 670.

In order to achieve a relatively substantial increase of anode wattage, use was made of metals having a higher melting-point than nickel. In America the tendency was toward the use of tungsten electrodes. German valve-makers generally used tantalum for the anodes. In this country molybdenum was in common use for anodes, and either molybdenum or tungsten for the grids. Such valves could deal with inputs of 5 kW or more, the anodes being capable of running with a steady dead loss of 1 to 2 kW.

The use of various grades of boro-silicate glass, known generally as "hard glass," not only allowed the bulb dimensions of this class of valve to be reduced but also permitted the use of tungsten or molybdenum leading-in wires to the various electrodes sealed directly to the hard glass, without requiring platinum or platinum substitute at the point of emergence through the glass bulb. The use of silica instead of glass for the envelope of transmitting valves with electrodes made of molybdenum and with forced air cooling of the silica bulb permitted the production of valves capable of operating with an anode loss of 10–15 kW, and operating at an anode voltage of 12–14 kV.

Lead was commonly used to form the seals for the leading-in wires of silica valves. These and the filament springing device were housed in long silica tubes projecting from the body of the bulb, in order to permit separate cooling of these parts. A paper on "Silica Valves in Wireless Telegraphy" was read before this Section in 1927 by H. Morris-Airey, G. Shearing and H. G. Hughes.*

To the almost unanimous forsaking of the oxide-coated cathode in favour of tungsten, coincident with the introduction of the hard valve, there was a notable exception in the case of the Western Electric Co. of America, who used a barium-strontium oxide-coated filament for repeater valves in 1915. The range of valve types using this "combined" filament was extended to include several transmitting valves of small power. The combined oxide-coated filament was adopted in Western Electric transmitting valves, large numbers of which were used in parallel in the wireless-telephone experiments of 1915 from Arlington, Virginia, to Paris and Honolulu. At about this time also the combined oxide-coated filament was used in the Western Electric transmitting types 211 and 212, which have continued in relatively unchanged form for more than 20 years until to-day. The design of these valves shows the early realization of the need to increase anode loading. This was done by the use of oxidized nickel for anodes, to approximate to black-body radiation. There was also a very early appreciation of the difficulties of grid emission, and the use of oxidized nickel was effective in reducing this trouble.

The largest example of this class of transmitting valve is the Standard Telephone type 4212, which has an output of 250 W as an oscillator. These oxide-coated valves are limited in anode voltage to about 2 000 volts, and in this respect differ radically from many of the glass valves previously described, whose normal anode potential is in the region of 10 000 volts.

Following the work of Coolidge, who in 1911 introduced thoria into tungsten filaments as used for electric lamps to increase their strength, Langmuir in a series of brilliant discoveries established the technique for procuring and stabilizing greatly enhanced emission from thoriated-

* *Journal I.E.E.*, 1927, 65, p. 786.

Plate 1

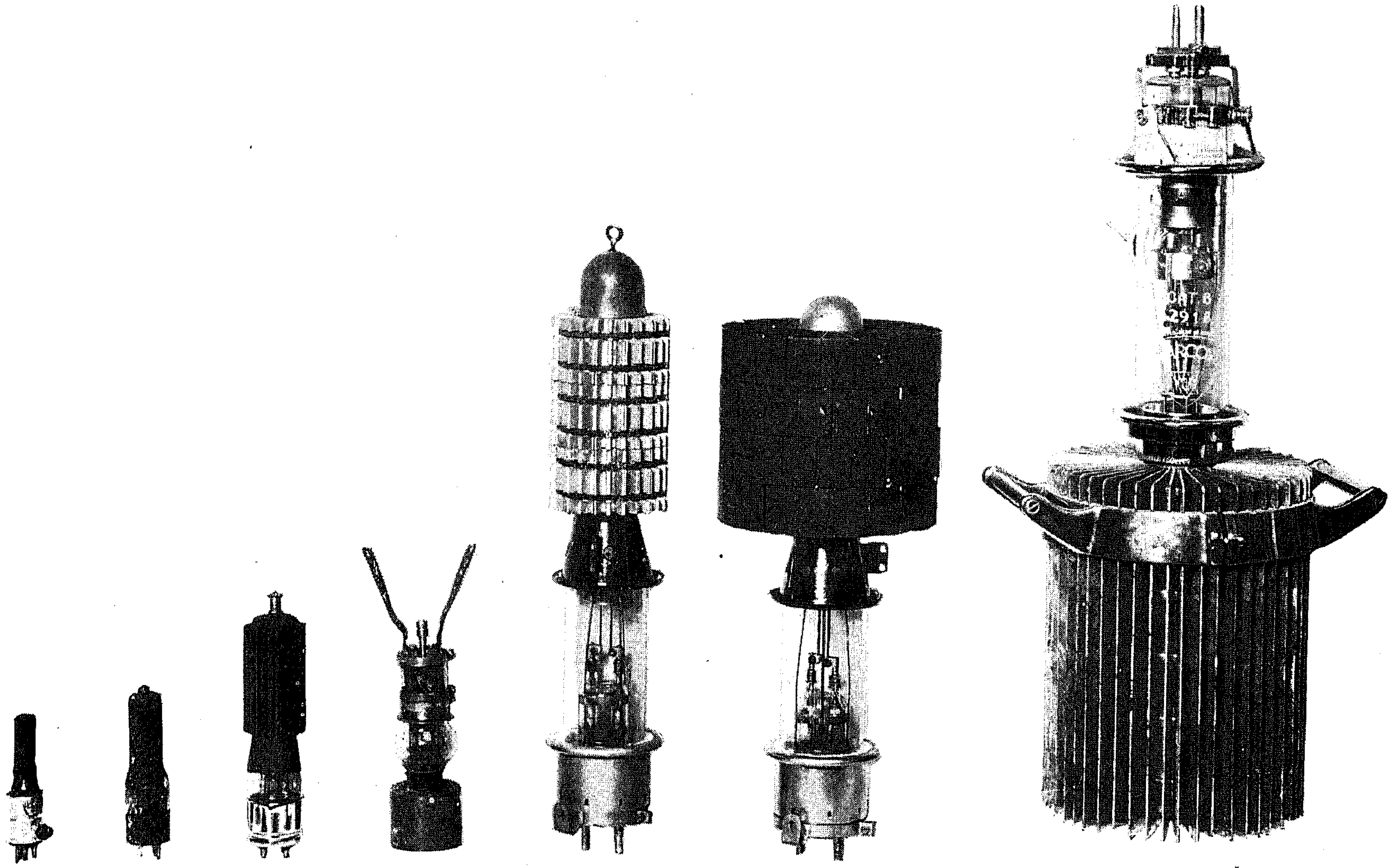


Fig. 2.—A range of air-cooled valves.

Left to right: Catkin receiving type and transmitting types having anode dissipations of 15 W, 75 W, 300 W, 1·5 kW, 1·3 kW, and 10 kW respectively.

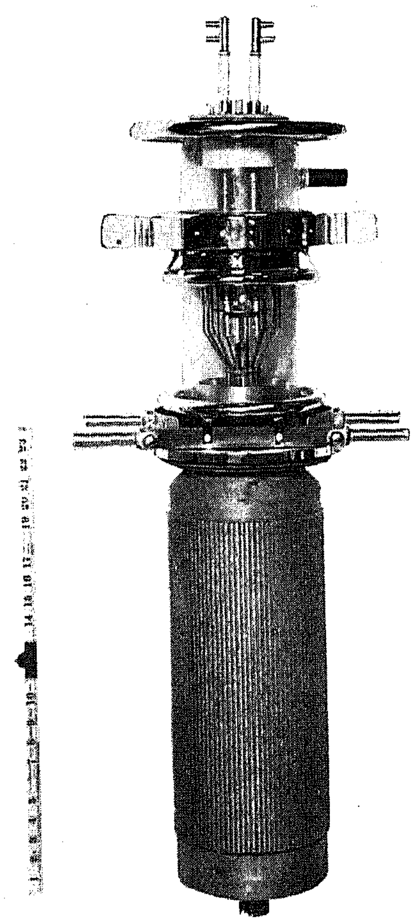


Fig. 1.—High-power cooled-anode transmitting triode for short-wave operation.

Class C ratings:
200 kW output at 200 m. (1·5 Mc./s.).
120 kW output at 13·5 m. (22 Mc./s.).

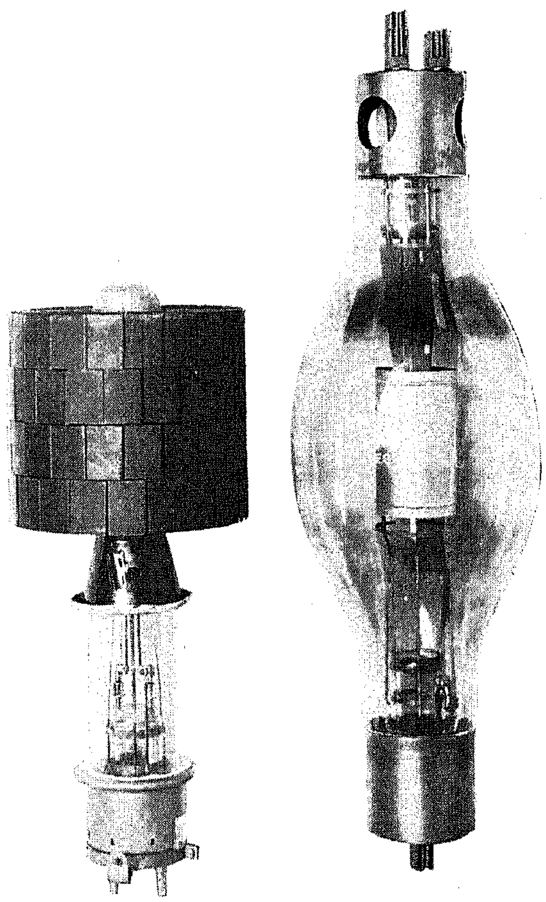


Fig. 3.—Different types with similar ratings.

Class C rating: 2·5 kW output at medium wavelengths, reduced output at short wavelengths.

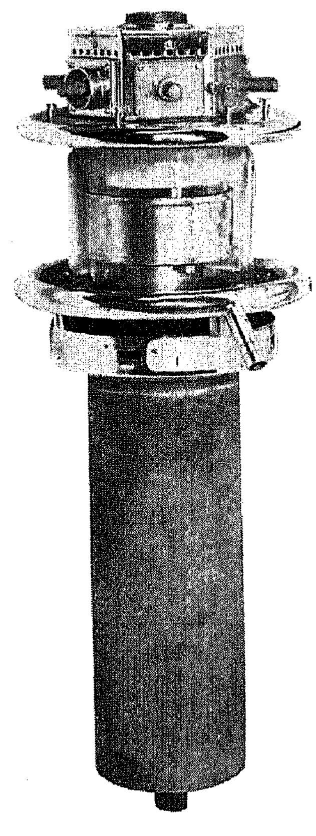


Fig. 4.—High-power transmitting pentode.

Class C rating: 40 kW output at 13·5 m. (22 Mc./s.).

Plate 2

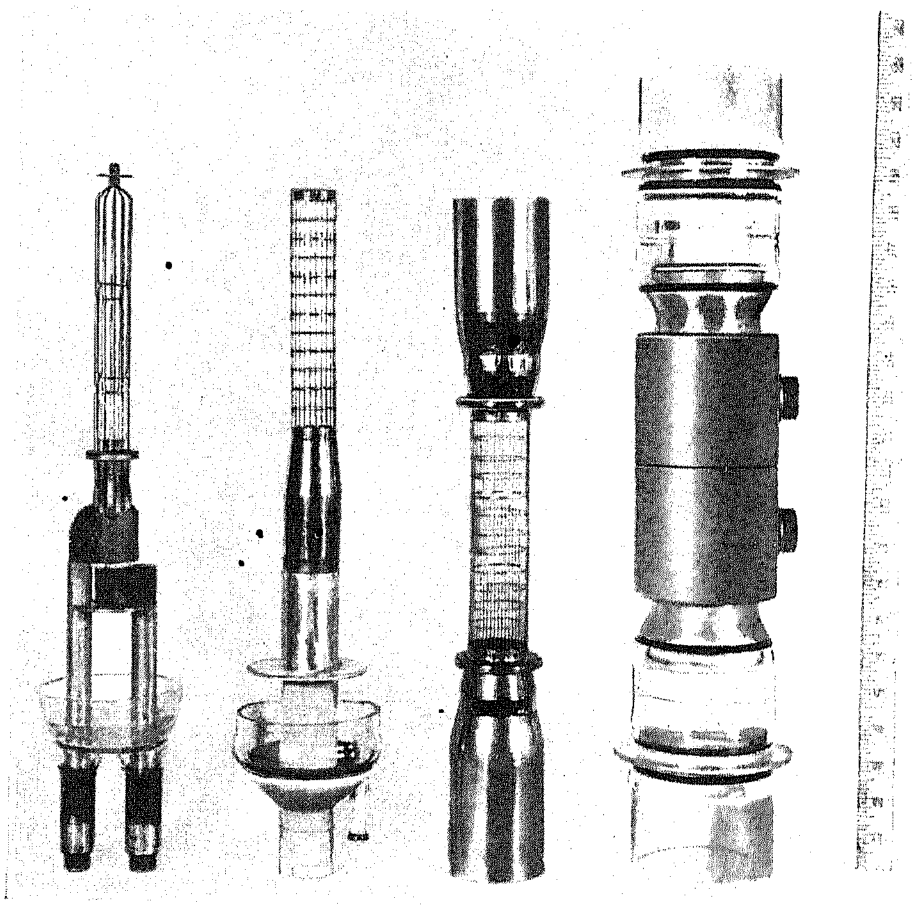


Fig. 6.—Electrodes of high-power water-cooled tetrode.
Class C rating: 35 kW output at 3·9 m. (77 Mc./s.).

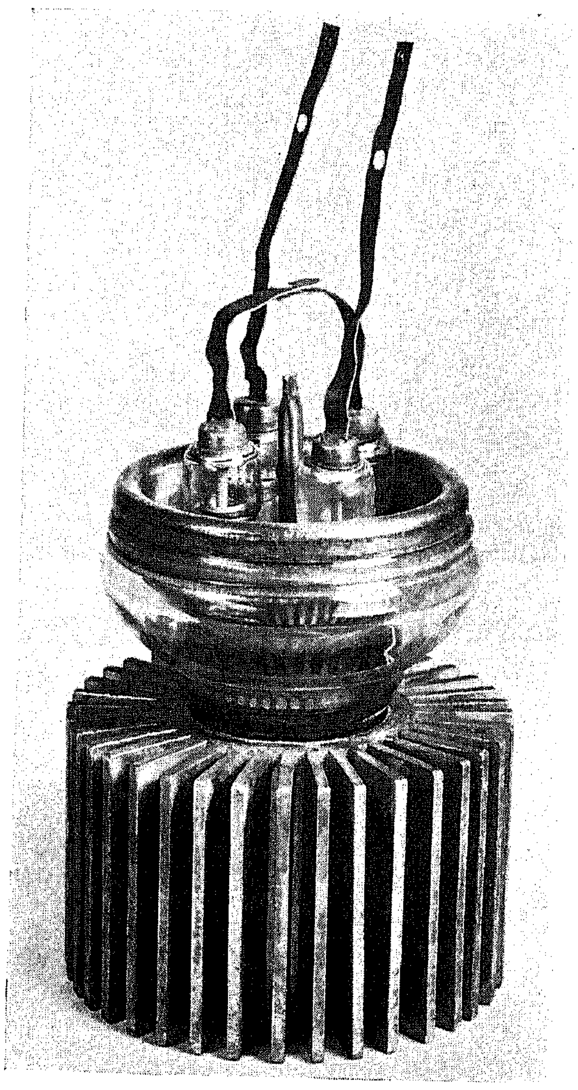


Fig. 5.—Radiation air-cooled beam tetrode.
Class C rating: 1·05 kW output at 2·7 m. (110 Mc./s.).

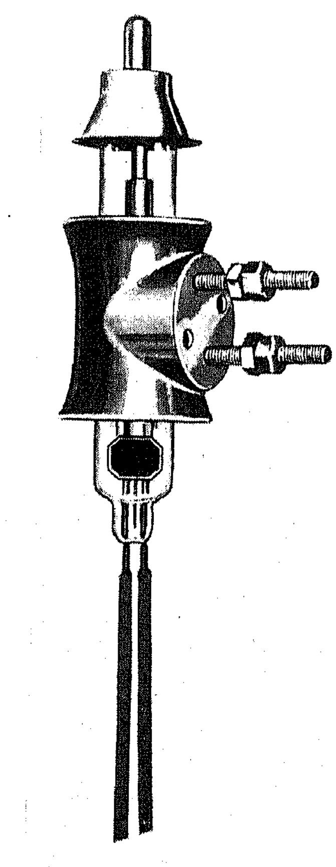


Fig. 7.—Water-cooled triode for ultra-high frequencies.
Class C rating: 800 W output at 1·33 m. (225 Mc./s.).

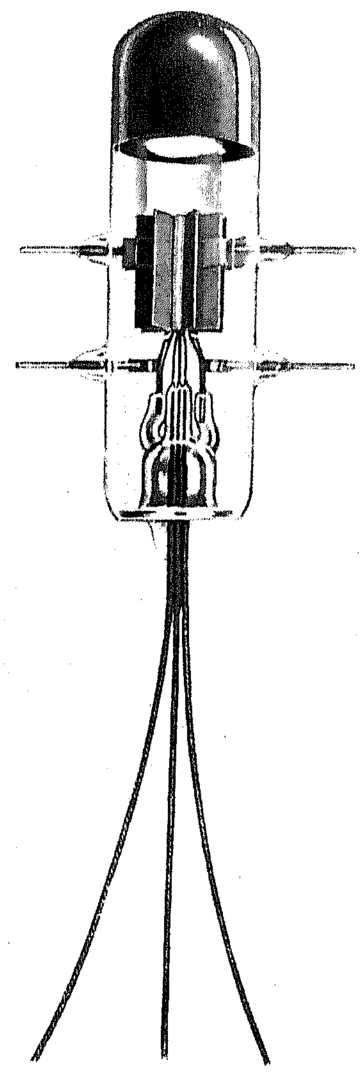


Fig. 8.—Triode for ultra-high frequencies.
Class C rating: 35 W output at 60 cm. (500 Mc./s.), reduced output at 43 cm. (657 Mc./s.).

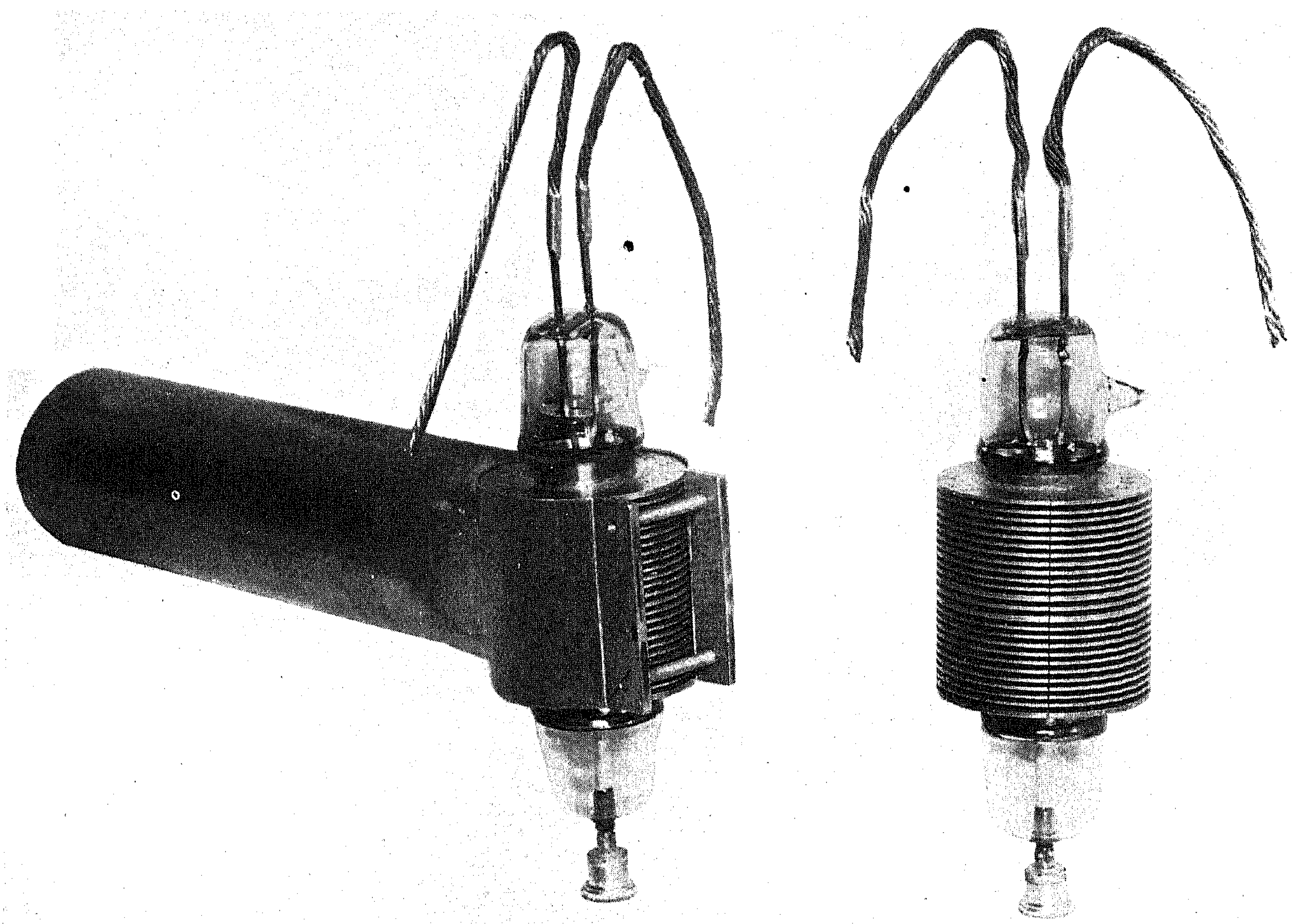


Fig. 9.—Air-cooled triode for frequencies up to 120 Mc./s.
When used with blower tube, as shown on the left, anode dissipation may be 300 W.

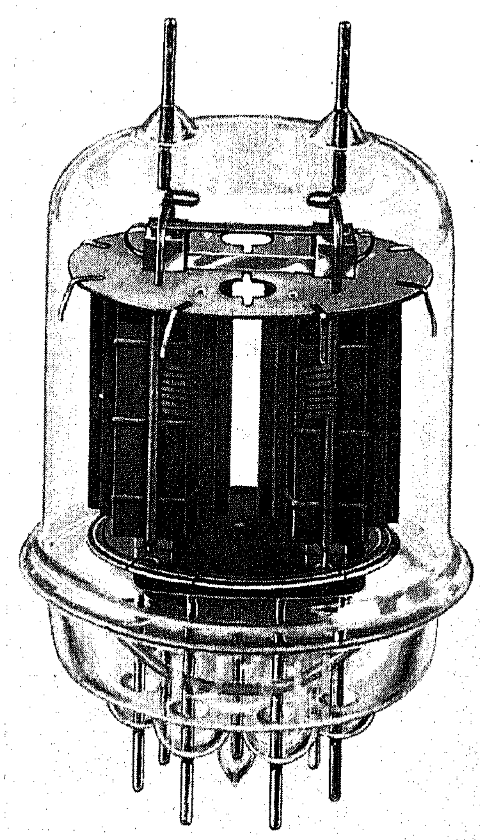


Fig. 10.—Push-pull beam tetrode. Class C rating: 120 W input at 1·5 m. (200 Mc./s.), reduced input at 1·2 m. (275 Mc./s.).

Plate 4

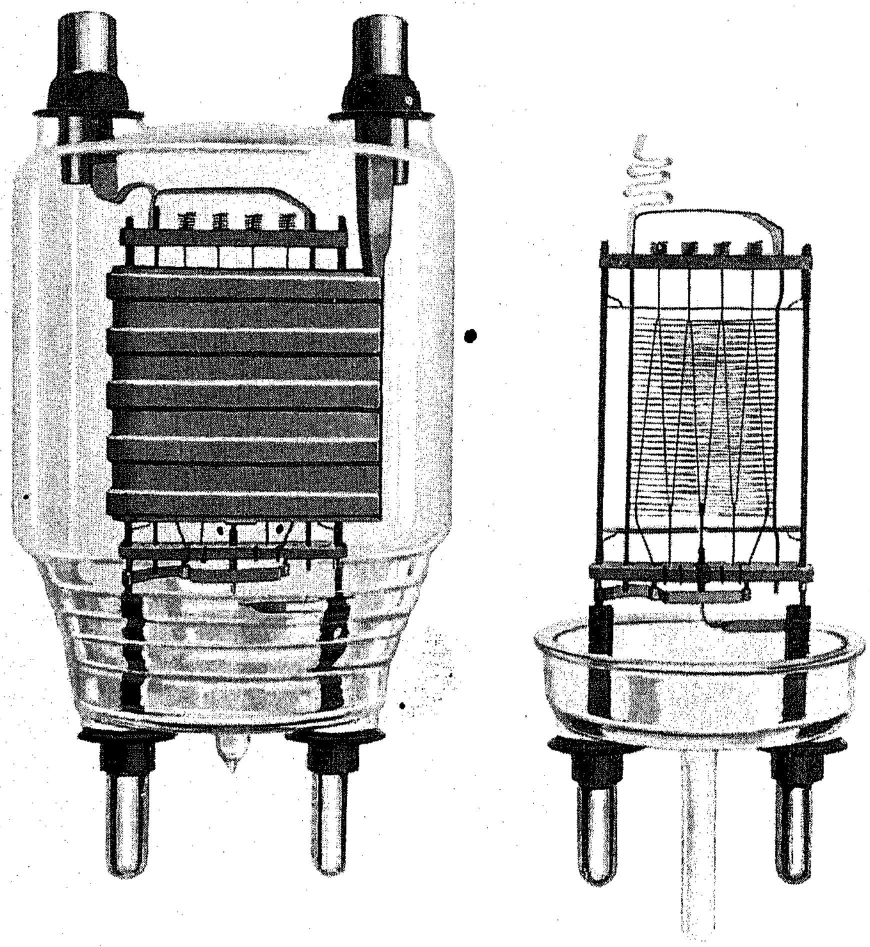


Fig. 11.—High-frequency triode.
Class C rating: 1 kW output at 10 m. (30 Mc./s.), reduced output at 3 m. (100 Mc./s.).

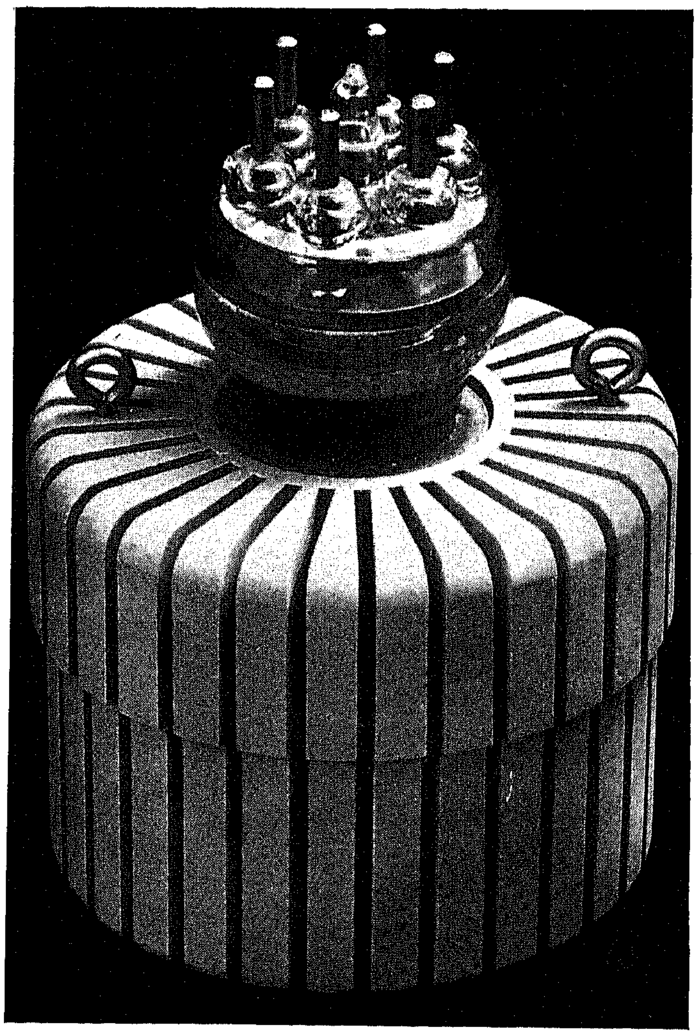


Fig. 12.—Air-cooled triode for high frequencies.
Class C rating: 1·8 kW output at 2 m. (150 Mc./s.), reduced output at 1 m. (300 Mc./s.).

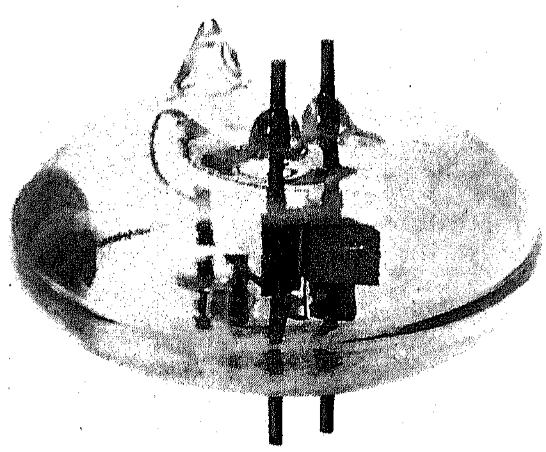


Fig. 13.—Triode for use at ultra-high frequencies.
5 W output at 25 cm. (1 200 Mc./s.), reduced output at 20 cm. (1 500 Mc./s.).

tungsten filaments. Thorium reduced from the thoria admixed with the tungsten diffuses from the interior to the surface of the filament where, if conditions are suitable, it forms, maintains and replenishes a monatomic layer of pure thorium. This monatomic layer requires less work to be done to release the electrons from its surface, and will stand a higher temperature without harmful effects than will a filament made entirely of pure thorium.

Thorium emission from thoriated-tungsten filaments has played a large part in the history of many classes of thermionic valves. Although it is not now used to the same extent in receiving valves as it was a decade ago, it is still used in many types of transmitting valves of the "dull emitter" class.

For many years the anode voltage of such valves was limited to 3 000–4 000 volts. Improved technique will perhaps remove this limitation. Already the Eimac Co. of America have a range of valves with an anode-voltage rating of 6 000 volts, and this has been achieved without the use of chemical getters. Should it be found possible to increase this voltage still further to a value approaching equality with that of pure tungsten-filament valves, without greatly increasing the cost, it would be a major step in the evolution of transmitting valves.

In the early twenties the need for higher-powered individual valves was obvious. Large numbers of valves working in parallel required larger and more expensive transmitters than would otherwise be called for, and presented certain circuit problems. There was a compensating advantage of high efficiency due in part to the high value of mutual conductance of the bank of valves. The silica valve, as used in the British Navy, was probably the outstanding example of high-power transmitting valves available at this time.

Various efforts had been made to increase the loading of glass and silica valves by circulating water through tubular spiral anodes. The seal between the tube carrying the cooling water and the valve envelope was the main difficulty, and here again the ingenuity of our transatlantic cousins provided a solution. It proved so elegant and simple that it was soon applied to many kindred problems, and so far-reaching have been its applications that we have not yet fully exploited its possibilities.

W. G. Housekeeper* in 1923 showed how base metals could be sealed to and through glass in a variety of ways. In particular, an illustration is given of how a copper cylinder having a coefficient of expansion of 17×10^{-6} was joined at one end to a cylinder of pyrex glass having a coefficient of expansion of 3×10^{-6}, and at the other end to a cylinder of lead glass having a coefficient of expansion of 9×10^{-6}. The copper is reduced in thickness to a knife edge at its junction with the glass. The Housekeeper seal immediately made possible the manufacture of high-power transmitting valves in which the copper anode formed part of the external envelope. Glass was relegated to the role of insulator between the various electrodes. The external anode could be cooled by means of water and made to dissipate tens of kilowatts.

In 1925 R. N. Vyvyan, at that time engineer-in-chief of Marconi's Wireless Telegraph Co., proposed cooling the external anode by means of forced air instead of by water. The proposal, although seriously considered, was not adopted by the valve designers, who feared the effects of allowing the anode temperature to rise above 100° C. It was not until several years later that this advance was achieved.

Very soon several types of glass-to-metal seals were being used in transmitting valves. Several manufacturers used the Housekeeper seal, in which, by virtue of the flexibility of the thin cylinder of copper at the junction, the coefficients of expansion of glass and copper need not be closely related. Other manufacturers used copper-plated nickel-iron less thin than in the Housekeeper seal, and more closely related in regard to coefficients of expansion with the glass to which it was united. Chrome-iron to lime-soda glass was used by another valve manufacturer. The filament seals showed even greater variety, including in addition to the above pure platinum thimbles; and later, when hard glass was used for part of the envelope, seals were made directly to electrode leads of molybdenum and tungsten.

The first water-cooled valves had a rating of approximately 25 kW input for Class C operating conditions, the permissible constant anode loss being of the order of 10 kW, the d.c. anode voltage 10–12 kV, and the filament power 50 amperes at 20 volts. These valves were soon required for broadcasting purposes, and as high-power anode-voltage modulation was the vogue at that time a demand arose for valves similar to the above (with the exception that the magnification factor or M value was much lower) to work as modulators under Class A operating conditions.

At the lower limit of M valve the grids of such valves consisted of a number of straight tungsten or molybdenum wires geometrically parallel to the filamentary cathode. Such an arrangement when working under Class A conditions gave rise to uneven heating of the anode by reason of the heat shadows projected by the grid wires on to the anode. Some interesting problems arose from this which, added to those associated with the conductivity of the cooling water and consequent electrical losses and corrosion of terminal points in the water cooling system, hastened the use of distilled water for cooling purposes. Distilled water in its turn presented difficulties when used for cooling the anodes of water-cooled valves. In some cases zinc from the galvanized pipes and copper from the copper pipes of the cooling system were deposited on the anode in an amorphous state, which did not permit good heat conduction from anode to cooling water. It was necessary to avoid aeration of the circulating distilled water, and if aeration did occur the use of de-oxidizing agents in the cooling water was found to be beneficial.

The commercial application of short waves in the "beam" wireless telegraph stations led to a demand for valves capable of giving their output efficiently at wavelengths of the order of 15 m. A demand had existed for some years before this time for valves of the smaller types for use on short waves, and this had resulted in modifications to the existing design of glass valves in the direction of heavier-current grid seals, shorter lead-in wires of higher conductivity, and glass envelopes free from metallic deposits. These latter, even when invisible, could give rise to "hot spots" due to eddy currents which resulted in the glass melting and imploding at the hot spot. A device for preventing such unhappy results, which might occur during

* *Transactions of the American I.E.E.*, 1923, 42, p. 870.

the sealed-off life of the valve and not necessarily during its manufacture, is known as the "Green-Gill" shield.

The larger types of glass or radiation-cooled valves were for the most part double-ended, the grid and filament being supported and the corresponding leading-in conductors sealed at one end and the anode and its conductor at the other. The advent of water-cooled valves gave rise to a simplification of design resulting in single-ended high-power valves.

In some cases, however, the demand for high-power short-wave valves resulted in a reversion to the double-ended type which permitted very heavy conductors to be connected to the grid. In order to reduce to a minimum high-frequency losses in the cooling of such short-wave valves, oil was used instead of water as the cooling medium. Careful selection of the cooling oil was necessary to avoid sludge and anode corrosion. The flash point had to be high enough to avoid danger of fire but not so high as to involve unduly elevated anode temperatures. Diffusers of a honeycomb design were fitted to the anodes of valves in order to increase the radiating area and reduce the working temperature of the anode.

To avoid the anomaly of calling valves cooled by means of oil "water-cooled valves," we called all valves having anodes which formed part of the envelope "cooled-anode valves."

One further type of cooled-anode valve should be introduced at about this period in the survey. The diode used as a power rectifier has had to compete with more efficient devices such as the mercury-arc and the hot-cathode mercury-vapour rectifiers, and has consequently not been used to such an extent as the transmitting and modulating valves of this class. However, the cooled-anode rectifier has certain merits which may be worth noting. A rectifying unit employing such valves is a relatively simple and rugged device, and economical of capital outlay and maintenance, especially if advantage is taken of the possibility of controlling the H.T. voltage by varying the cathode emission by means of the filament voltage. The absence of a grid to act as a Faraday cage between the cathode and anode exposes the filamentary cathode to the full force of the electrostatic field of the anode. In some rectifier circuits, during the half-cycle when no anode current is flowing the anode voltage reaches a very high value. Perhaps the simplest way to make a rectifying valve is to omit the grid from a transmitting valve. Such a rectifying valve may fail, through the filament bowing owing to the electrostatic action of the anode voltage. The remedy we adopted was to squeeze the anode along its length midway between the two legs of the filament so as to form an anode having a binocular cross-section, each filament leg being concentric with that portion of the anode surrounding it. Valves of this type have been in operation for many years, providing in 3-phase half-wave circuits a d.c. output of 500 kW at 20 kV, the H.T. d.c. voltage being controlled by means of the filament voltage of the rectifier valves.

In a paper entitled "Gas-Filled Thermionic Tubes"* A. W. Hull describes a fundamental principle of thermionic gas-tube operation, by which cathode disintegration may be entirely avoided. Disintegration occurs when ions with more than a definite kinetic energy bombard the cathode, the critical value for common inert gases being between 20 and 25 volts. This voltage is higher than that necessary to produce ionization. Therefore the advantages of ionization can be obtained without the disadvantage of short cathode life, if the voltage drop between cathode and anode is kept below this critical value. This can be done by ensuring that the cathode electron emission is always greater than the maximum peak space current. Oxide-coated cathodes are used in power rectifiers of this class, which are generally known as hot-cathode mercury-vapour rectifiers. The combination of such a cathode with the low voltage-drop essential to its longevity gives us a rectifier of the highest efficiency.

* *Transactions of the American I.E.E.*, 1928, 47, p. 753.

By suitable choice of the mercury vapour pressure the voltage drop during the conductive half-cycle can be made sufficiently low to prevent cathode disintegration whilst permitting voltages greater than 20 kV between anode and cathode during the non-conductive half-cycle when the anode is negative with respect to the cathode. Suitable circuits have been devised to permit the highest d.c. voltages consistent with the limitation imposed by this peak inverse voltage.

Hot-cathode mercury-vapour valves have been standardized up to powers in excess of 600 kW in a 3-phase full-wave circuit employing six valves.

In the paper mentioned, A. W. Hull also describes hot-cathode gasfilled devices in which the space current is controlled by means of a grid. These "thyratrons" have been used as gasfilled relays since 1928, and more recently grid control of hot-cathode mercury-vapour rectifiers has been extended to valves of greater power. By this means the d.c. voltage of a rectifying unit employing such valves can be varied from zero to full working volts during the starting-up period of a transmitter. The method also permits a very rapid removal of the H.T. volts, which prevents damage to the valves during short-circuits external to the valves.

Grid-controlled mercury-vapour rectifiers are available rated at 11 kV, 1·5 amperes, for operation from a 3-phase full-wave circuit.

Increase in size and power of individual valves incurred certain disadvantages. One has been mentioned before in this survey, namely the lower efficiency of the single high-power unit as compared with that of a number of smaller units of equal total power. The other, called "flash-arcs," has been described by B. S. Gossling.* These discharges occur mainly between the supports to the electrodes at the cooler end of the valve, the parts that are not subjected to heavy bombardment during the pumping process. They were associated mainly with single-ended valves operated at anode voltages greater than 10 kV, and were most serious in valves used in circuits employing large capacitances and small inductances. Improved valve and circuit technique have so effectively combated this phenomenon that it is mentioned mainly as a matter of historical interest. Many hundreds of valves have been operating for thousands of hours at anode voltages up to 20 kV without a single flash-arc.

Before passing to the consideration of higher-power cooled-anode valves, in order to avoid too great a disparity in time I shall at this point make mention of demountable valves.

A valve which when new costs several hundred pounds,

* *Journal I.E.E.*, 1932, 71, p. 460.

becomes inoperative due to filament burn-out after a normal life and is then of little or no value. The user may be tempted to ask: Why cannot the filament be replaced and the valve repumped in situ? The answer is that many valve manufacturers have experimented with continuously evacuated demountable valves, and it is evident from American and other sources that experiments on these lines are being continued.

C. F. Elwell in 1927 read a paper* before this Section on the Holweck demountable valve continuously evacuated by means of a Holweck rotary molecular pump. In 1935 C. R. Burch and C. Sykes presented before this Section a paper† entitled "Continuously Evacuated Valves and their Associated Equipment" which recorded the very real advances made in this field, especially in the development of low-vapour-pressure oils and greases, used respectively in the oil-vapour pumps and vacuum-tight joints of these valves. The improved vacuum obtained by the use of such pumps has doubtless contributed largely to the perfecting of continuously evacuated valves. In avoiding the necessity for using liquid air the operation of such valves in any part of the world has been made practicable.

Demountable valves, not necessarily continuously evacuated, will take their rightful place in the family of thermionic valves. The fundamentals of the case are economic: the initial cost of demountable valves will always be more than the equivalent cost of sealed-off valves, and skilled staff is required for demounting, renewing, remounting and re-evacuating. Where many similar high-power units are used in one central radio transmitting station the demountable valve should be able to compete with its sealed-off brother. When high frequencies are required for industrial purposes with unlimited power the demountable valve should excel.

The power of broadcast transmitters was being stepped up very sharply at this time, and there was an insistent demand for valves capable of standing higher anode loss and of operating at a higher anode voltage.

The next advance was the development of cooled-anode valves capable of dissipating 50 kW loss at the anode at a working voltage of about 16 kV. This was rapidly followed by an improved design with an anode voltage of 20 kV and 75 kW anode dead loss. These were generally used as high-frequency power amplifiers under Class B operating conditions.

It was necessary to reduce to a minimum distortion introduced by the valves acting as amplifiers of the carrier which had been modulated at low power in an early stage of the transmitter. This had to be done whilst achieving the highest output from the valve and conforming to international regulations which required higher quality and less distortion of broadcast transmissions coincident with the increase of power.

Valve characteristics were closely scrutinized in order that the quality of broadcasting might be improved. As an example, high valve efficiency demanded high mutual conductance and therefore small clearance between grid and filament. Under these conditions the magnetic field of the filament exercised a considerable effect on the linearity of the valve characteristics by increasing the grid current at the expense of the anode current. Secondary emission at the grid surface had to be held within close limits. The electrostatic field of the grid had to be as uniform as possible in order that control of the space current might be effectively linear at all values of current down to zero current; in other words, in order that "tail" due to "islands" of uncontrolled space current might be avoided.

It was not long before another big step forward was made in the power-handling capacity of individual valves. A typical example is the CAT.14, the chief characteristics of which are: Anode volts, 20 kV; anode dead loss, 150 kW; filament voltage, 32 volts; filament current, 460 amperes; amplification factor, 45; mutual conductance, 50 milliamperes per volt; emission for normal life, 100 amperes; dimensions, 1 200 mm. × 420 mm.

Two of these valves working as a power amplifier in the final stage of a broadcast transmitter give an output of 120 kW carrier power, capable of being modulated 100 % and conforming to international regulations.

Valves were approaching the limit of man-handling size and weight, and it was necessary to bear this in mind when considering the design of high-power valves. Several factors contributed to the relatively small size of the CAT.14. The following may be mentioned here: (1) Single-ended construction, i.e. the grid and filament are supported and their conductors sealed-in at the same end. (2) The filamentary cathode structure has no springing arrangement. It is a self-supporting cage bonded at several equipotential points and weighted by gravity. (3) The anode radiating surface is increased by rectangular corrugations.

Nickel-iron alloy is used at the glass-to-metal joints of the CAT.14 valve. The glass part of the envelope has a high lead content and is opaque to the X-rays which are generated at normal operating voltages. The filament leads external to the bulb but forming an integral part of the valve, are formed of concentric tubes so that they can be cooled by water or by forced air throughout their length right up to the filament seals.

The short-wave version of the CAT.14, called the CAT.17, is shown in Fig. 1 (see Plate 1, facing page 40). A copper cylinder is sealed to, and forms part of, the glass envelope at a sufficient distance from the anode to be effectually insulated therefrom. This cylinder supports the grid and provides a low-impedance path able to carry the very heavy high-frequency current which occurs in the grid circuit in short-wave operation.

Two of these valves are used in the final stage of high-power short-wave broadcast transmitters rated at 100 kW carrier output at 20 m., operating at an anode voltage of about 11 kV under Class C conditions with anode-voltage modulation.

It had been intended, had it been possible to read this Address at a Meeting of the Wireless Section, to show lantern slides of several valves of comparable power to those just described, in order that notice might be directed to the variety of designs evolved by technicians in the several countries.

The Telefunken Company's R.S.300 differs considerably from similar types made in other countries, in that it has a cathode which is not filamentary but tubular. The tube may be made of columbium, and the return path of the cathode current is a conductor inside, and concentric with, the tubular cathode. The cathode tube carries the full current,

* *Journal I.E.E.*, 1927, 65, p. 784. † *Ibid.*, 1935, 77, p. 129.

and approximately half the voltage drop is across that part of the current path. It is therefore not truly indirectly heated; the heating is partly direct and partly indirect from the heat generated in the return path. The magnetic field set up by the current in the tubular cathode is neutralized by that of the current in the return path so long as these remain accurately concentric, to achieve which a powerful spring is provided. The cathode of this valve can be heated by alternating current without thereby modulating the carrier to such an extent as to introduce a hum audible on broadcast receivers.

The cathode of the R.S.300 requires 35 kW at 18 volts. The emission is 200 amperes and the mutual conductance 200 milliamperes per volt (max.). The anode voltage is limited to 10 kV. Two valves in push-pull as a power amplifier in the final stage of a broadcast transmitter give a carrier output of 120 kW. The dimensions of the R.S.300 are 1 800 mm. × 420 mm.

On first consideration heating the cathode of a valve by means of alternating current would appear to be an easy and obvious process. For receiving valves the solution was the indirectly heated cathode, and this is also applicable to small transmitting valves; but for transmitting valves of higher power than about 100 W other methods have had to be found. The incentive has been the elimination of rotating machinery associated with d.c. cathode heating and the smaller cost and physical dimensions of the apparatus required for a.c. heating. The disadvantage has been introduction of hum into the radiated carrier wave due to magnetic or electrostatic modulation of the space current in the valve by the a.c. power used to heat the cathode. One method successfully employed was that of the concentric lead-and-return cathode, as exemplified in the Telefunken type R.S.300. This solution, although effective, was costly and was not generally adopted. A more economical method obviously was the use of biphase or polyphase filaments.

At an early stage 3-phase filaments were fitted in individual valves, but it was found that although the lower harmonics were reduced in amplitude the higher harmonics of the supply frequency were more pronounced, and as these frequencies came well within the audible range of broadcast receivers various means were employed experimentally to balance out this residual hum. Amongst these methods was negative feedback. This was not acceptable to some of the principal users, and consequently 3-phase filaments were not adopted at that time.

Two-phase filaments gave rise to harmonics of a lower frequency, and for that reason were preferred. A convenient compromise was made in using standard valves with the filaments of pairs of valves in push-pull heated by alternating currents with their phases in quadrature.

In modern broadcast transmitters negative feedback is accepted as standard practice for the reduction of distortion, and as a result 3- and 6-phase filaments are now coming into use for transmitting valves.

An example of polyphase filaments is the American General Electric Company's GL.893 valve, which has 6 filament terminals and can be operated as 6-phase, 3-phase, single-phase or direct-current.

The experience gained with cooled-anode valves using oil as the cooling medium proved that the anodes of standard valves could be operated without detriment to life at temperatures considerably higher than those normally encountered with water-cooled valves.

Le Rossignol and Hall* gave particulars of these and also of conditions of imperfect water cooling which caused the anode temperature to rise to 250° C.

A range of receiving valves were developed in 1932–33 in which the anode formed part of the envelope. These were called Catkin valves, owing to their likeness to cooled-anode transmitting valves. An essential difference was that the anodes were air-cooled instead of water-cooled or oil-cooled.

At the same time small transmitting valves were developed on Catkin lines with anodes fitted with fins and blackened to give effective cooling by radiation. Larger valves followed in which forced-air cooling of the anode was used. In 1935 the A.C.M.1 modulator valve of this class, capable of dissipating 1·5 kW anode dead loss, was produced and used in broadcast transmitters.

Fig. 2 (Plate 1) shows a range of these valves in which the anode forms part of the envelope. Some are cooled by radiation and others at maximum loading by forced air. The largest is the air-cooled version of the CAT.6 valve, capable of dissipating 10 kW.

Fig. 3 (Plate 1) shows (on right) one of the largest radiation-cooled glass valves, the Ediswan ES.1500A, alongside a radiation-cooled valve in which the anode is part of the envelope. The valves have comparable ratings.

To-day broadcast transmitters of 50 kW carrier power are made using forced-air-cooled valves throughout in place of water-cooled valves. The highest power cooled-anode valves will soon be available for cooling either by means of water or by means of forced air.

In order to minimize noise and to obtain the most uniform distribution of the cooling air the tendency is towards designs of fins and orifices which permit the circulation of large quantities of air at low pressure. Some of the advantages of forced-air cooling as compared with water cooling are: (1) Economy in space owing to the elimination of primary and secondary water tanks, reservoirs and coolers. (2) Elimination of high-frequency losses in the water column. (3) Less total cost. (4) Lower maintenance costs.

The evolution of the transmitting valve is often influenced by that of the receiving valve, but there is usually a considerable lapse of time between similar advances in design of the two types. Transmitting tetrodes followed shortly after receiving tetrodes, but high-power transmitting pentodes have been in use for a comparatively short period.

Meanwhile, the receiving valve goes merrily along adding electrode to electrode. It is to be hoped that the transmitting valve will not be forced to follow far along the same path.

Tetrodes and pentodes offer advantages in that neutrodyning is avoided and a greater amplification per stage is achieved. Advantage is taken of the pentode design in certain classes of radio-telephony to use the suppressor grid for the function of modulation. Four-electrode valves constructed with aligned grids, known as "beam tetrodes," have been developed to give characteristics similar to those obtained in the conventional pentode. Transmitting beam

* *G.E.C. Journal*, 1936, 7, p. 176.

tetrodes and pentodes are now made to handle considerable power and very high frequencies.

Illustrations and data relating to some of these are shown in Fig. 4 (Plate 1) and in Figs. 5 and 6 (Plate 2).

It is only a few years since 15 m. was regarded as the lower commercial limit of short wavelengths. A spectrum of radio frequencies published in *Electronics* in 1930 showed as the "commercial" range of wavelengths 30 000 m. (10 kc./s.) to 13 m. (23 Mc./s.). A similar spectrum published in 1940 still stopped at 30 000 m. (10 kc./s.) on the longer wavelengths but extended to 10 cm. (3 000 Mc./s.) at the ultra-high-frequency end of the spectrum; all of these frequencies were grouped as "used in radio-communication."

Exploitation of the ultra-high-frequency field is in its early stages. The transmission of television and frequency-modulated broadcasting with the wide wave-bands essential to their efficiency, linking-up by radio of such transmitters, facsimile broadcasting by radio, multi-channel radio-telephone links between wire telephone systems, blind-landing and beacon guidance for aeroplanes, and the rapidly expanding military requirements are making heavy demands on the wavelengths between 1 and 10 m., which until recently were scarcely used. The demand is therefore for valves—both receiving and transmitting—which will generate efficiently considerable high-frequency energy at decimetre and even centimetre wavelengths.

Great ingenuity has been shown in modifying the conventional triode in order that it may operate efficiently at the highest possible frequencies. In the larger valves this has been in the direction of so arranging the design that the inter-electrode capacitances are a minimum and the leads to the electrodes are as short as possible and have high conductance and low inductance.

It would be difficult to give clear descriptions of various designs of ultra-high-frequency valves, but it may be of interest to give illustrations of a few of the many interesting variations [see Figs. 7 and 8 (Plate 2), Figs. 9 and 10 (Plate 3), and Figs. 11–13 (Plate 4)].

The conventional transmitting valve, utilizing space-charge control, is limited ultimately in generating or amplifying higher frequencies by the time taken by the electron in passing from the cathode through the control grid to the anode. This limit has been reached, and if effective use is to be made of the almost unlimited channels of communication on wavelengths of less than 1 m. other means of controlling and harnessing the electron stream in the thermionic valve must be used. As Gossling* puts it: "There is still, however, the new field where the periods of electrical oscillation are so short that electron inertia is no longer negligible, but has itself to be brought into service as a main principle of action."

The current passing through a vacuum between cathode and anode is dependent on the charge on the individual electron, the density of electrons and the velocity of the electron stream. The unit charge of the electron cannot be changed. Density control by means of space charge is limited by transit time. There remains the control or modulation of the velocity of the electrons, which may give us new weapons more potent than any yet provided by the thermionic valve. Many workers in this field have already provided a variety of electronic devices that in varying degrees and in several ways overcome the limitation and make use of the transit time of the electron.

The Barkhausen–Kurz circuit, in which the grid of a triode is given a potential higher than that of the anode, has been used experimentally for many years. Standard Telephones and Cables, Ltd., used positive-grid micro-wave valves in their radio-telephone tests across the Straits of Dover in 1931, on a wavelength of about 18 cm. Marconi and Mathieu also used positive-grid valves developed especially for a series of experiments and demonstrations carried out in Italy during the years 1931 to 1934 on wavelengths of 60 cm. and below.

The split-anode magnetron has been successfully used in many demonstrations at very high frequencies during the past decade, and is undoubtedly a valuable instrument for this purpose. Although a great deal of work has been devoted to the split-anode magnetron in many research laboratories and not a few papers have been read and published on this subject, its commercial application has been very limited. In part, this has been due to difficulty in frequency-control and modulation of such valves. One feels, however, that if there had been a real demand for split-anode magnetrons the technical difficulties would have been sooner overcome.

The RCA.825 inductive output valve, rated at 35 W output at frequencies above 300 Mc./s., has an efficiency of 60 % at 500 Mc./s. It has a normal type of grid, controlling or modulating the density of electrons; focusing electrodes for forming these into a beam; and a resonator in which high-frequency energy is induced by the modulated beam of electrons as they pass on their way to the collecting anode.

A velocity-modulated valve developed at Stanford University utilizes a resonator for modulating the electron beam, and this modulated beam induces the output into a similar resonator. These resonators are hollow metal enclosures, and those used in this particular valve are dumb-bell-shaped and are called "rhumbatrons" (from the Greek *rhumba*, signifying rhythmic oscillations).

Separating the beam into packets and compressing them has been compared to the effect of water breaking up into waves at the beach edge. The waves thus formed are compressed and, mounting in height, suddenly topple over and break. The Greek word *klyzo* describes this action; hence the designation " klystron " for this valve.

The simplest form of the klystron includes two resonators or rhumbatrons, and the operation is as follows: (1) Electron beam generated at cathode is phase-focused by first externally-excited rhumbatron. (2) The beam, now velocity-modulated, drifts to the phase focal plane at which the grids of the second rhumbatron are positioned. (3) Second rhumbatron is set into oscillation by phase-focused beam.

The American writers are more picturesque; they describe the operation thus: "Electron beam generated at cathode and is bunched by the buncher. Bunched beam caught by the catcher."

The second rhumbatron, being at the phase focus, oscillates more powerfully than the first; thus the high-frequency amplifier comes into being. An output of 300 W at 10 cm. has been recorded.

"Drift-tube" velocity-modulated tubes, developed by engineers of the American General Electric Company, are

* "The Perfection of the Thermionic Valve," *Nature*, 1935, 135, p. 748.

described in a very interesting paper by W. C. Hahn and G. F. Metcalf.*

Suitable valves must be available before experiments in transmission can be carried out in any new field of radio-communication. After the necessary research work on a new valve has been completed experimental tests under working conditions are essential to the successful completion of the design of the valve. Life tests are necessary before manufacture in quantity can be safely undertaken. Such tests on large valves can only be carried out on commercial, broadcast or similar transmissions owing to the long life of such valves, running into thousands of hours, and the high cost of power and supervision. If any of the above facilities or services are not available, delay will inevitably occur in the provision of suitable valves and associated apparatus, and this delay may have serious repercussions.

* *Proceedings of the Institute of Radio Engineers*, 1939, 27, p. 106.

I wish to express my thanks to Mr. R. McV. Weston for his kindness in affording facilities to view his very interesting private collection of valves; to the American General Electric Company, the Radio Corporation of America, Messrs. Eitel and McCullough, Standard Telephones and Cables, Ltd., and the Mullard Radio Valve Co., Ltd., for technical information; and to my colleagues, particularly Messrs. L. H. Norballe and L. M. Myers, for their kind assistance.

TRANSMISSION SECTION: CHAIRMAN'S ADDRESS

By H. J. ALLCOCK, M.Sc., Member.*

While it is to be hoped that conditions will later improve to such an extent that it will be possible to conduct our affairs on a more normal basis and hold Section Meetings, the present stage of hostilities has unfortunately necessitated the abandonment of meetings of the Transmission Section for the first half of the Session. This Address cannot, in consequence, be read in open meeting; I have therefore only the opportunity which the *Journal* affords of thanking the members of the Section for the high honour they have done me in electing me their Chairman for this Session, and of saying how much this honour is appreciated. It will be my endeavour to serve the Section to the best of my ability and to further its interests on all occasions.

Again, it is unfortunate that the Section will have no opportunity of thanking publicly the outgoing Chairman, Mr. F. W. Purse, for the services he has rendered us during the past session; and I am sure it would be your wish that I should express our appreciation of his services during a very difficult session in which he has assisted materially in the progress of the Section.

The Transmission Section is now entering the seventh year of its history. The Section was formed at the beginning of the Session 1934–35, and at the end of the first year the membership was 1 572; the membership has now increased to 1 692. While these figures show good progress, it must be remembered that the total membership of The Institution, both corporate and non-corporate, is slightly greater than 20 000, so that the membership of this Section is only some $8\frac{1}{2}$ % of that of The Institution. The rule dealing with the activities of this Section states that: "The Section shall include within its scope all matters relating to the study, design, manufacture, construction, maintenance and/or operation of transmission and distribution lines, both overhead and underground, for purposes other than those of electrical communication." It would seem, therefore, that there are still many members of The Institution who are fully qualified to become members of the Section but who have not yet done so. It may be that an impression is abroad that, providing one has the necessary qualifications and interests, membership of the Section is automatic. It must be pointed out, however, that this is not so, and that those who are interested must make application for membership of the Section. I hope that this explanation may assist in rectifying the position, and that those who are qualified, but have not yet become members of the Section, will do so in the near future. An ever-strengthening Section must be a healthy body, and it would be a source of great satisfaction to me if I might vacate the office of Chairman at the end of my term with a record increase in membership.

During the period of a major war such as this, the whole efforts of an industry such as ours must be devoted to its prosecution to a successful termination. The greater proportion of the research work and technical advances of the present time is designed towards this end, and is generally of so confidential a nature that it cannot at present be disclosed. While, therefore, I am unable to discuss these matters at the moment, it will be found, when disclosure is possible, that the war effort of the electrical engineer has been considerable, both in volume and in technique, and has assisted materially in the successful and speedy determination of the issue.

The necessities of the moment require that the maximum of materials and labour should be made available for the war effort, and one way in which substantial transference to the war-time needs can be made is by the simplification of existing standards for underground cables. In the past the cable industry has suffered from a multiplicity of standards, with the result that production has not been of the most economic type. The dimensions of power-transmission cables are specified by the British Standards Institution, but, unfortunately, in spite of the issue of new Standards in 1933 (B.S. No. 480), there has always been a regrettable tendency for use to be made also of the obsolete Standards contained in B.S. No. 7—1929. Recently, however, the Electricity Commissioners have made the use of B.S. No. 480 mandatory (with certain exceptions in the case of non-standard voltages), and this has eased the situation somewhat and has also resulted in a saving in both material and labour. But although the elimination of B.S. No. 7—1929 results in the reduction of the number of Standards, I consider that the new Standards in B.S. No. 480 cover too many sizes and types of cable to permit, at any rate in the case of the lower voltages, of economic bulk manufacture and withdrawal from stock. It is suggested that considerable further economies could be made by adopting the following five proposals.

(1) In the case of twin and multi-core cables both shaped and circular conductors are specified. Except as regards the very smallest conductors there is no reason why shaped conductors alone should not prove sufficient. Modern methods of manufacture result in a shaped-conductor twin or multi-core cable which is perfectly satisfactory in service, and experience in installation has shown that no inherent difficulties exist in jointing or teeing-off.

(2) The number of sizes of conductor covered by the Specification is 22, ranging from 0·007 sq. in. to 1·5 sq. in. If certain of the intermediate sizes were eliminated, no hardship would be felt in designing transmission and distribution lines, and further useful simplification would result. The sizes which could most readily be deleted from the Specification without undue loss of economy or efficiency are given in the Table, together with the next smaller and larger standard sizes.

* Callender's Cable and Construction Co., Ltd.

Table

Sectional area of conductor, sq. in.		
Next smaller standard size	Size to be deleted	Next larger standard size
0·007	0·01	0·0145
0·0225	0·03	0·04
0·06	0·075	0·1
0·1	0·12	0·15
0·75	0·85	1·0

(3) The present Standards contain separate designs for cables for use on 3-phase systems (*a*) in which the centre-point is earthed and (*b*) in which the centre-point is not earthed. It is, however, unusual to find a system in which the centre-point is not earthed by being connected either solidly to earth, or through a resistor of negligible resistance. I would therefore suggest that there is no need for both types of cable to be covered by the Standards; and if there do exist exceptional circumstances where, say, from the point of view of added safety it is desirable to use an increased thickness of dielectric such as is afforded by the unearthed type of cable, then the earthed type of cable for the next higher voltage covered by the Standards could be used. This, of course, does not apply to low-voltage cables in which the thicknesses of dielectric between conductors and between conductors and the lead sheath are the same.

(4) There are at present two different voltages of cable, both of which are used for low-voltage distribution systems, namely the 460-volt and the 1 000-volt cable. It would seem redundant to have two, and it is suggested that the 460-volt cable could be eliminated.

(5) Another factor in the construction of the cable, which in the past has added to the complications of manufacture (more especially in the case of distributor and service cables), is the method of core-distinguishing. Prior to the issue of B.S. No. 480 no colour scheme had been standardized for the cores of paper-insulated cables, but the colour scheme which appeared in B.S. No. 480 was not popular and was not adopted by the majority of supply authorities. This was, in some way, due to the difficulties involved in adopting two different colour schemes in extension work, and users have therefore generally adhered to their own particular schemes which they have used for a number of years. With a view to solving this difficulty of extensions it is now suggested that colours should be abandoned and core-distinguishing should be by numbering, the numbers being printed on the outer paper of each core at frequent intervals. It is preferable to have white numerals on a dark paper background, so that they may be readily distinguished in jointing pits. If such a scheme were adopted it would be a simple matter for each user to determine his core-distinguishing scheme, allocating to each number the colour which was appropriate in his own case. Again, in the interests of standardization, where the conductors are not all of equal area, the smallest conductor should bear the highest number. In this way it is possible always to have the phase cores numbered 1, 2 and 3 respectively, whether in a 3-, 4- or 5-core cable.

The appropriate way of effecting these simplifications would be by the issue of a new Standard, and these matters have been under consideration by the British Standards Institution. The present time, however, is not one for wholesale alteration of Standards; in spite of this fact, a great deal of the simplification could be carried out by active collaboration between the user and the manufacturer, and I earnestly suggest that this collaboration should be effected immediately so that the greatest degree of simplification can come into being as quickly as possible.

Further essential war-time economies in material can, and must, be made by reducing, if necessary, the safety factor of underground mains. Such an economy in the non-military use of steel has been effected by the Electricity Commissioners prohibiting the use of armour on cables, except in certain cases where the difficulties of, or special conditions in connection with, the route involved require the use of armour as an essential safety factor. Where cables are laid alongside railways or over railway or road bridges, vibration may be anticipated and, in such situations, a substantial fabric bedding and armour are essential. Armour is also essential in situations liable to subsidence. In addition, the control and telephone cables used in conjunction with important transmission schemes are especially required to remain in service when the main feeders have been damaged, and it is therefore essential that these auxiliary cables should be armoured and thus have the highest degree of immunity from damage by enemy action.

It is not contended that an unarmoured cable is as immune from damage as an armoured cable: but the saving in steel which can be effected by the elimination of armour must be made. In order to provide the most satisfactory unarmoured cable, the pure lead sheath, which is normally used when cables are armoured, has been replaced by a sheath made of one of the alloys specified in B.S. No. 801. This provides a somewhat harder sheath which will assist in laying and, by reason of the smaller-grained crystal formation, will offer a slightly better resistance to chemical corrosion. Since there is little to choose between the alloys in these directions, the choice is left to the individual manufacturer. The sheath is further protected by a waterproof serving, which can be provided in one of the three following forms (placed in order of merit):—(*a*) 2 paper tapes, 1 cotton tape, 1 hessian tape; (*b*) 2 paper tapes, 2 hessian tapes; (*c*) 2 paper tapes, 1 layer of jute yarn.

Further simplification is possible by a correct choice of the method of specifying the cable when it is purchased. The purchaser may issue a detailed "materials" specification, or he may issue a dimensional specification with requirements as to performance. The former may possibly tie down the manufacturer to the use of materials which are not best suited to the conditions of service, whereas the latter enables full advantage to be taken of the manufacturer's advances in technique of manufacture and the use of materials as and when they occur. In this way, the more satisfactory cable is obtained and in addition the greatest simplification in manufacture is assured.

If the purchaser is to be satisfied by such a specification it is essential that the manufacturer should be possessed

of an efficient and active research department, and also that the technical control of manufacture should be complete and effective. By "complete" I mean that the whole of the factors which affect the efficiency of the finished product should be under unified control. The design of the product, the selection of the raw materials, the detailing of manufacturing processes, and the testing of the finished product are included in this category.

I consider that the simplifications and economies which can be achieved by all the foregoing methods are a direct addition to the wartime effort which has to be made by everyone, but especially by the engineer.

All that has been said so far has been said in the light of the present crisis; but it is equally applicable to post-war development.

War produces scientific advances, the material and lasting advantages of which appear later. It is, of course, impossible to predict with accuracy what will be the trends of post-war development, but it is reasonable to assume that there will be an even greater use of electricity than in the past. The necessity will therefore arise for a reinforcement of the Grid interconnection system. In all probability this will mean transmission at even higher voltages than are used at present. In any case, urban development will necessitate the use of more underground cable in place of overhead line for transmission purposes.

Let us therefore consider the progress in the design of high-voltage cables. In the transmission of electric power at voltages of the order of 11 kV, a multi-core cable of the belted type has proved perfectly satisfactory. This is in spite of the fact that the dielectric within the electric field is non-homogenous by reason of the presence of fillers of different permittivity, which are inserted to make the cored-up cable circular in cross-section. Although the non-homogeneity leads to distortion of the electric field, and so gives rise to tangential stress in the dielectric, these tangential stresses are unimportant until the operating voltage is raised above 20 kV. As the operating voltage of the system is increased, however, the electric stress in the dielectric has to be increased, since otherwise the thickness of dielectric and the overall dimensions of the cable would become prohibitive, both from an economic and from a manufacturing point of view. At the higher stresses the tangential stresses become important and, in addition, if the cores separate, owing to heating on loading, gaseous spaces are formed which, at the high stress, tend to ionize and so shorten the life of the cable.

In the screened type of multi-core cable, however, this situation does not arise: each insulated conductor is separately screened by means of either a metallic or a metallized tape, or a lead sheath; any fillers which are necessary are outside these screens, and therefore outside the electric field. Tangential stresses, therefore, are not present; and even if vacuous spaces do form by separation of the cores, they will not be inside the electric field, so that no ionization can occur or deleterious effects take place.

It must be realized that the prevention of the occurrence of vacuous spaces *within* the electrical field becomes of greater importance as the working dielectric stress is increased. Even the most minute space may become larger under operating conditions and, while these are of no importance at low electrical stress, they become important at high electrical stresses owing to ionic bombardment. The spaces may contain gas at so low a pressure that, under the influence of the electrical stress, the gas in these spaces becomes highly ionized and consequently conducting. The development of intense ionization in these spaces is likely to shorten the life of the cable. Firstly, the chemical activity of the gas when thus maintained in an ionized state may lead to chemical change in the hydrocarbons present, especially by the formation of permanent gases; this process, in turn, tends further to enlarge the spaces. Secondly, the chemical activity of the ionized gas may be such that it leads to a gradual but progressive degeneration of the surrounding insulation.

It is unfortunate, therefore, that the normal impregnating compounds have a higher coefficient of expansion with temperature rise than the remainder of the materials used in the cable. In consequence, under conditions of loading, when the temperature is raised, the excess volume of compound is expelled from the dielectric, and this compound never returns on the removal of load and consequent cooling, because there is not sufficient restoring force. Gaseous spaces at low pressure may therefore be formed, generally near the conductor, at the region of highest electric stress; and the problem of high-voltage cable design and operation is the prevention of the formation of such spaces or, if they do form, the maintenance of them under sufficiently high pressures to prohibit ionization. In 30-kV and 66-kV cables, the formation of gaseous spaces of dangerous dimensions may be prevented by making conductors oval in cross-section. It has been found that an oval core, as it expands under the influence of heat, becomes more circular in cross-section, thus enclosing within a given periphery a greater cross-section than it would have done had it retained its original ratio of major to minor axis. In this way, the excess compound expansion is to a large extent catered for, and if gaseous spaces do occur on cooling they are generally so small that, at the stress which they experience, they have no deleterious effect upon the life of the cable.

At higher working stresses, however, even the small gaseous spaces which may be formed in an oval-conductor cable become dangerous, and the suppression of ionization has to be accomplished by other means. Three well-known types of cable, employing pressure as a suppressor, are available, namely the oil-filled, the oilostatic and the gas-pressure types.

In the oil-filled cable, longitudinal ducts are provided either in the conductor or (in the case of the multi-core cable) in the filler spaces. The cable is impregnated with a very fluid compound and, in operation, the compound is always kept under a positive pressure by means of compound pressure tanks and ancillary equipment arranged at feeding points along the route. In addition, the question of remanent gas is taken care of by the characteristics of the compound, which, specially degasified, will take gas into solution rather than give it up under stress. The oilostatic system, which is somewhat similar, has been in use in the U.S.A. The cable, either single-core or multi-core, is drawn into a steel pipe-line, the lead sheath (which is used merely as a protective covering during transit) being removed as the cable enters the pipe. The pipe-line system containing the cable is then dried out and filled

with degasified compound, and a positive pressure maintained on the system by means of tanks and automatic pumping devices at intervals along the route length.

Maintaining the stress field full of oil at all times is a highly complicated matter and requires constant running maintenance, but the gas-pressure cable system does not suffer from these disadvantages. In this type of cable, a positive pressure is maintained in the dielectric by means of a gas under pressure between the dielectric and the pressure-retaining sheath. Any gaseous spaces which may form in the dielectric are always kept under a sufficiently high pressure to prevent ionization and deterioration. A normal type of construction is sufficient, subject to the requirement that the lead sheath must be reinforced by means of circumferential and longitudinal metal tapes to withstand the high gas pressure, of the order of 200 lb. per sq. in., which is maintained on the outer surface of the dielectric. Gas pressure is provided at certain feeding points from gas cylinders through regulating valves. This type of cable combines the desirable simplicity of the normal type with the added safety of the more complicated systems. No abnormal precautions are necessary during installation, and the design and construction of joints and sealing ends offer no serious difficulties compared with those for the normal type of cable.

It will thus be seen that, as the operating voltage was increased, the design of the high-voltage cable at first became more complicated; but that later developments, in spite of further increases in operating voltages, have been towards simplification. The great mileage of cable employed in the transmission of electric energy in this country prompts me to suggest that further simplification in design is needed so that the complications of running maintenance may be further reduced. The only way in which this can be achieved is by a reversion to the "straight" type of cable, which can only be done by the use of new dielectric materials and perhaps also the development of new technique in the method of their application to the conductors. Research in these directions is at present being made to meet the needs of war; but it is to be hoped that it will finally find its peace-time outlet and will result in improved amenities for the general body of the peoples of the post-war world.

As for the problems of transmission at the present time, they are too immediate and pressing for reference to be made to them, and it must be left to a future Chairman of this Section to trace their interesting technical history. It is devoutly to be hoped that the moment when disclosure will be possible is not far off, and, indeed, nearer than so many of us yet dare to expect.

ABSTRACTS OF PAPERS

[Date of publication and the Part in which each paper will appear are shown in parentheses.]

A METHOD FOR DETERMINING THE RESTRIKING CHARACTERISTICS OF POWER NETWORKS WHILST IN SERVICE

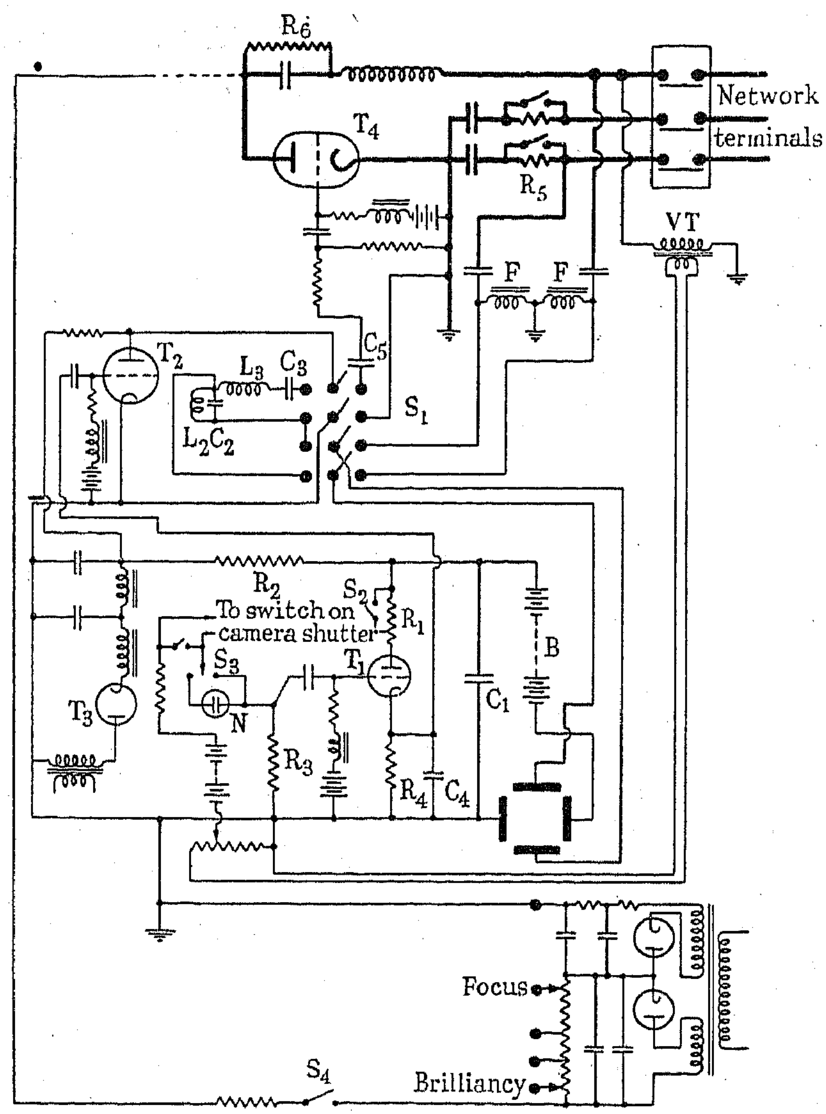
By C. DANNATT, D.Sc., Member,* and R. A. POLSON, B.E., Associate Member.*

(ABSTRACT *of a paper which will be published in February in Part II of the Journal.*)

The paper describes a method which has been developed for measuring the restriking-voltage characteristic at any point of a power network, without interruption of the supply and without producing surges in the system of more than a few hundred volts. The accuracy of the test results has been confirmed by comparing them with records taken on a switchgear testing-plant by means of (*a*) a recurrent-surge oscillograph used with no excitation of the network, and (*b*) a high-speed rotating-film cathode-ray oscillograph operated at the time of a short-circuit test. These comparisons were made on the network connected for and excited at 6·6 kV and 33 kV. Further tests were carried out at two substations of an electric supply undertaking on the 6·6-kV 3-phase busbars.

The principle of the method is to measure oscillographically the voltage response of the network to a current surge in which a constant rate of change of current is maintained for several hundred microseconds. The surge is produced by connecting an inductor across the system terminals at the instant when the power-frequency voltage passes through its maximum value. A condenser is placed in series with the inductor to limit the current drawn from the network, but since the natural frequency of the inductor and condenser is chosen to be 500 c./s. or less, a linear increase of current is maintained for a sufficient time to enable voltage transients containing frequency components down to 5 kc./s. to be faithfully recorded. The voltage appearing at the network terminals consists of the power-frequency voltage on which is superimposed, in the region of the peak value, a transient equal to the restriking voltage corresponding to the value of di/dt used for the injection, and directly proportional to it in magnitude. The network voltage is applied to one set of plates of the cathode-ray oscillograph through a high-pass filter network which suppresses the 50-cycle voltage and leaves only the transient voltage to be recorded. A single-sweep linear time scale is applied to the other plates of the cathode-ray oscillograph, this being synchronized with the moment of application of the current surge in the well-known manner. A standard high-voltage sealed-off cathode-ray tube is used, with a blue fluorescent screen, but the tube is operated at 50% over-voltage. Ample photographic sensitivity to a single trace is obtained with any standard high-speed orthochromatic film. A 50 kc./s. timing wave is provided for calibrating the time scale of the records. The surge is injected into the power network through the medium of a high-voltage discharge tube, or alternatively a 3-ball spark gap. The former has distinct advantages, since there is no follow-up of power current. If the 3-ball gap is used a breaker must be provided for interrupting the power current, which consists of the charging current to the condenser in series with the injection inductor.

The complete circuit diagram is shown in the Figure, in which the heavy lines at the top of the diagram indicate the injection circuit connected to the network terminals. The sequence of operations is as follows: The camera



shutter is opened, closing the contacts shown in the diagram. When the next peak of power-frequency voltage at the network terminals is reached, a biased neon lamp N fires, and gives an impulse across the resistor R_3, tripping the thyratron T_1 in the time-sweep circuit. The current flowing in R_4 in series with T_1 causes a voltage-drop which trips the thyratron T_2 a few microseconds later. This discharges the condenser C_5, which causes the operation of T_4, or the breakdown of a 3-ball gap, and initiates the surge into the network.

The restriking voltage for a line-to-earth fault on a

* Metropolitan-Vickers Electrical Company, Ltd.

3-phase system with earthed neutral requires the injection to be made between line and neutral, but for the first phase to clear of a 3-phase-to-earth fault on a system with an insulated neutral it is necessary that two of the phases be short-circuited to earth, as far as high frequencies are concerned. This condition is simulated for the purpose of the tests by condensers connected from these two phases to earth.

In most of the examples of tests given in the paper it was possible to check the measured restriking rate by calculation, and reasonable agreement was found in all such cases. The effect of system load on the restriking voltage was also demonstrated by test, and it is pointed out that load conditions may prevent testing under conditions leading to the highest possible restriking rates. In such circumstances it is suggested that it may be necessary to combine the measurement method with calculation based on the estimation of corrections for the effect of load, or alternative network connections, in order to arrive at the worst condition.

VOLTAGE-OPERATED EARTH-LEAKAGE PROTECTION

By T. C. Gilbert, Associate Member.

(Abstract *of a paper which will be published in June in Part II of the Journal.*)

The author stresses the need for a more practical consideration of the requirements for an efficient means of leakage protection, and suggests that in the search for safety from shock the equally important matter of protection against fire has been neglected. He urges that there is only one criterion upon which safety methods can be judged: Do they unfailingly provide the protection needed, or are there factors under the control of others which will vitiate their efficiency?

The author considers that the methods at present in use or now undergoing consideration by research bodies and others, viz. earthing and protective multiple earthing, have proved themselves incapable of providing the necessary degree of protection against fire and shock. It is pointed out that neither of these systems is capable of easy and efficient test, and that mere resistance tests cannot indicate the presence of oversize fuses, an increase in the setting of overload circuit-breakers, or the current-carrying capacity of the earth-continuity conductor. Extracts from a recent Home Office publication are quoted to show that even the resistance of screwed steel conduits, the most efficient wiring system from the mechanical aspect, cannot, in spite of the greatest care in erection, be kept to the low value of 1 ohm as required by the Wiring Regulations.

In an Appendix a further quotation is made from this publication, affording details of a disastrous fire caused by a comparatively high earthing resistance, although in the installation concerned supply was taken from a transformer on the premises and the usual difficulties associated with earth-electrode resistance should not apply.

The author then shows how, in certain small installations in London, considered to be almost perfect from the installation standpoint—copper-clad cables soldered at junctions to ensure continuity, protection by means of Zed fuses rated at no more than 2 amp., and with a resistance to earth, including the electrode, of only 0·5 ohm—earth faults caused no less than 39 fires in one year by reason of the cables coming into contact with composition gas pipes. The author argues from this that it is quite impossible to forecast by calculation the probable voltage rise on earth-connected metal immediately prior to the blowing of a fuse, as in these cases the voltage rise on the small installations would hardly have exceeded 3–4 volts. It has been found from experiment, however, that much higher voltages than this are necessary for the puncturing of gas pipes and the firing of the escaping gas, and probably the current flow must be continued for an appreciable time.

The author also mentions the frequent instances of apparatus and appliances damaged beyond repair with the occurrence of internal earth faults, intensified by the installation of oversize fuses, generally necessary where small motors are started direct-to-line or are subjected to short-duration overloads. It is also discussed whether leakage protection should be extended to all non-electrical metalwork in any building, owing to the fact that conduits, equipment, etc., are often mounted on steel structural work or are in other intended or fortuitous contact with such metal. The author advocates the interconnection of all metal, as is required by I.E.E. Wiring Regulation 1002 for all rooms containing a fixed bath.

The question of expense incurred in providing these heavy but inefficient earth-continuity conductors is also discussed, and the view is advanced that protective systems must be evolved which can be made quite independent of the variable factors now vitiating protection by earthing or protective multiple earthing. The author also considers that some form of simple test for the protective circuit is essential, and that this must be capable of application by unskilled persons, even the consumer himself. In the author's opinion these requirements are met in the system now in use on the Continent; and he therefore describes the operation of the system by a large power company operating in the west of Germany with which he has had some association, namely the Rheinisch-Westfaelisches Elektrizitätswerk.

The system is applied to the low-voltage lines emanating from the substation and to consumers' premises, and the device evolved for the protection of rural overhead lines is shown diagrammatically in Fig. 1.

Where neutral protection is employed the device operates whenever the potential between the neutral line and earth

exceeds 65 volts, which may be due to contact between the neutral and a phase line. The leakage trip will also operate in the event of the voltage on the phase lines exceeding 250 volts to earth in a 220/380-volt system, as this implies that the neutral potential is displaced by 52 volts. Further protection is afforded against a voltage drop of more than 125 volts in the earthing system, caused by the entry of the high voltage into the low-voltage side, by a transformer fault, or by the passage of fault current over the high-voltage earth-plate affecting the low-voltage earth-plate.

The auxiliary earth connection may possess resistance, and the test value for this is generally 50 ohms, easily secured in any soil. This electrode is installed in addition to the main electrode—upon which there is much less dependence—and away from any effect due to voltage gradient from the latter electrode. Over 1 000 rural substations are now equipped with this device. In addition to efficient leakage protection, the overload arrangements are such that the most efficient loading of the rural lines is possible, and remote short-circuits between phase and neutral are isolated by means of a simple thermal trip in the neutral line.

The operation of the leakage trip on the substation switch is delayed, according to local conditions, but the trips fitted to consumers' switches are instantaneous. These are brought into operation by a potential difference of 65 volts relative to earth on the protected metal casings, with an earth-electrode resistance of 800 ohms, which is considered to be the least favourable condition met in practice. With an electrode resistance of 200 ohms—a more usual value—and a potential difference of 22 volts the switch operates within two alternations of the supply voltage. The switches may in addition be fitted with overload trips, and in this form are often employed by supply authorities for the termination of services. The more usual type,

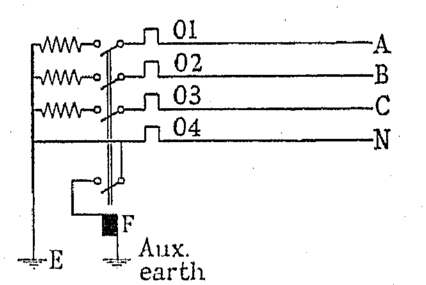


Fig. 1

01, 02, 03, 04 = Thermal overload trips.
F = Leakage trip coil.
E = Main earth.

however, is that designed for leakage protection only, overload protection being by means of the usual cartridge fuse in the phase lines only. As a single-pole switch is not permissible, the leakage switch invariably interrupts the neutral line as well as the phase lines.

As the operating currents involved are so small, now about 60–70 milliamp., and the occurrence of a resistance of a few ohms in the protective circuit is unimportant, this circuit is often made by means of small insulated conductors, similar to bell wire, drawn into conduits, which are often of the insulated variety. This facilitates simple and effective sectionalization of the protective circuit, leading to very efficient protection and at very low cost. Electrodes are usually of a simple type, the 4-ft. rod or pipe providing all that is necessary, although in some districts a few yards of galvanized iron wire are buried 1 ft. or 2 ft. down and continued up into the earth terminal

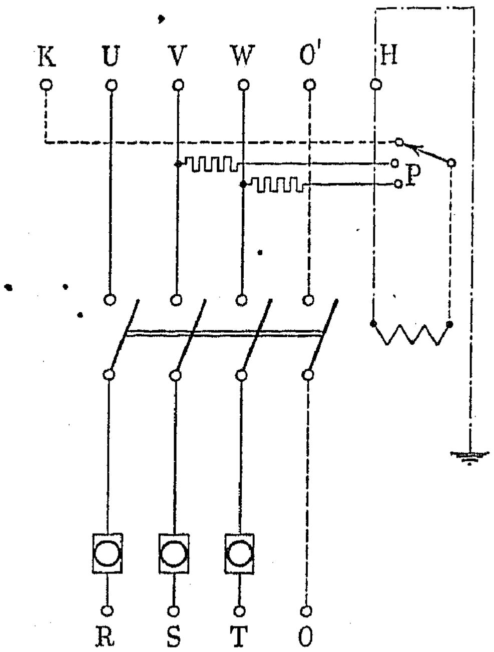


Fig. 2

of the switch. This forms a very cheap electrode, practically proof against corrosion, and there are no junctions to become discontinuous.

In the author's view, however, one of the greatest assets of the system is its extreme ease of test. Testing requires no skill or expensive instruments, and in some cases may be made automatic. In Fig. 2 the standard connections for the 4-pole device are shown, and it will be seen that a test key is provided, making contact with one, or two, phase lines, and thereby imposing an artificial fault on the switch. This key checks only the electrode and its connection and proves the switch mechanism; but a test of the complete protective circuit can be made by short-circuiting the phase-contact-tube of a 3-pin socket-outlet to the earth contact-tube, or, in any apparatus with exposed elements, by short-circuiting the live terminal or element to the earthed frame. One electrode only is provided at each installation, together with the main or sub-circuit leakage-trips connected to this electrode. A separate electrode is invariably provided, and connections are not made to water pipes or cable sheaths, even if available. This enables all metal to be bonded, if required, and to share in the leakage protection.

Earth connections for isolated apparatus are not run back to a central point but are made to a near-by electrode; even structural steelwork, fencings, or gas pipes have been used for this purpose, but for farm equipment a simple spike driven into the ground near the motor provides all the protection necessary. This considerably reduces the cost of connecting 3-phase motors situated some distance from the point of supply, as only the phase lines need be installed.

THE APPLICATION AND USE OF QUARTZ CRYSTALS IN TELECOMMUNICATIONS

By C. F. Booth, Associate Member.*

(Abstract *of a paper which will be published in June in Part III of the Journal.*)

INTRODUCTION

The piezo-electric crystal has played a major role in the advances which have been realized in the telecommunication art during the past 10 years, and without its aid many of the radio-frequency generation and selection problems could not have been solved. Of the several crystalline substances possessing the piezo-electric property, quartz, tourmaline and rochelle salt have been used in telecommunication.

The Post Office has been actively concerned for many years with both the application and the production of the quartz crystal and, as the Department's experience is considered to be representative of the art, it is felt that an account of the work may be of general interest.

THE QUARTZ CRYSTAL

When the quartz crystal is subjected to mechanical stress of which there is a component along an X axis, electric charges are released on the crystal surfaces, and, conversely, mechanical stresses are developed when the crystal is electrically polarized. An alternating field will cause the crystal to vibrate, the oscillation intensity being small

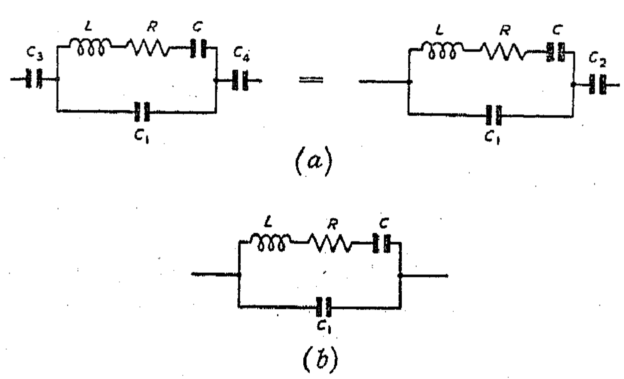


Fig. 1.—Equivalent circuit of a quartz crystal.

(a) With air gaps. $C_2 = C_3C_4/(C_3 + C_4)$.
(b) Without air gaps.

unless the frequency of the applied potential approaches coincidence with a natural period of the crystal, in which event resonance occurs and comparatively large charges are developed.

To apply the alternating field the prepared crystal (plate or bar) is mounted between metal electrodes, and for analytical purposes the mounted crystal may be represented by the equivalent electrical circuit of Fig. 1. By virtue of the piezo-electric coupling which exists between the mechanical vibration and the associated electrical circuit, the crystal may be caused to self-oscillate at one of its natural frequencies in any of the circuits of Fig. 2.

The decrement of the crystal is small (values of 0·00001 have been obtained) and, in consequence, the oscillation frequency is determined primarily by its natural period, the circuit effects being of a secondary order. In view, therefore, of the durability and low temperature-coefficients of expansion and elasticity of quartz, the frequency stability of the quartz-controlled oscillator is of an order unobtain-

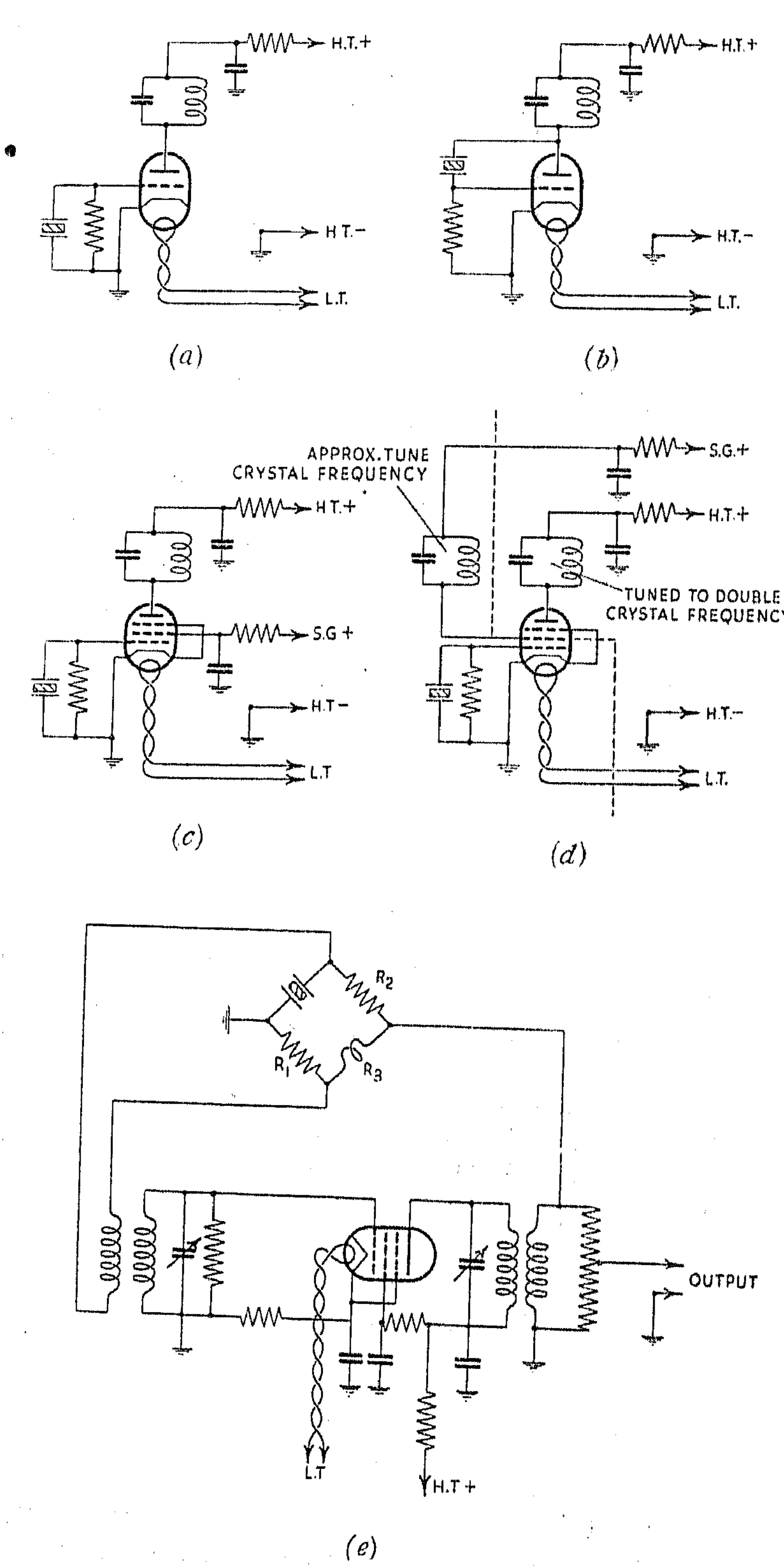


Fig. 2.—Quartz-crystal oscillator circuits.

(a) Triode crystal-oscillator grid-cathode connection.
(b) Triode crystal-oscillator grid-anode connection.
(c) Pentode crystal-oscillator.
(d) Pentode crystal-oscillator and doubler.
(e) Bridge-stabilized oscillator.

able with coil and condenser oscillators at the present state of the art, long-period stabilities of $\pm\ 10/10^6$ are feasible with simple equipment, and stabilities approaching a few parts in 10^8 may be realized with more complex apparatus.

The natural frequency (f) of a crystal is approximately inversely proportional to the length (l) in the direction of oscillation, being given by $f = k/l$, where k is the fre-

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quency constant. The value of k is dependent on the type of oscillation, the shape and the relation of the prepared plate or bar to the crystallographic axes of the natural crystal, i.e. the cut, and it varies between the limits 1 500 and 3 500 kc./mm. It is practicable to produce crystals of fundamental frequencies in the range 50 to 20 000 kc./s. and to extend the range from audio frequencies to 300 000 kc./s. or higher, by frequency dividers and multipliers. For frequencies below 400 kc./s. it is usual to employ a bar oscillating in the length mode, and for higher frequencies a plate vibrating in the thickness mode. Many types of cut are in use, but, in general, cuts giving a frequency/temperature coefficient of less than $\pm 2/10^6$ per degree C. are employed. The safe power dissipation of a crystal employed for radio-frequency control is very small, and amplifiers are necessary when powers greater than a few watts are required.

To achieve the ultimate stability of the crystal, the vibration must not be damped by the mounting system, which should not introduce any variable in the equivalent circuit. The design of the mounting differs according to the particular application.

Another use to which the quartz crystal has been put, and which may be even more widely practised than the oscillator application, is as resonator elements in electric wave filters. The low decrement makes practicable the design of radio-frequency filters with frequency characteristics which cannot be achieved with the filter employing only coil and condenser elements. In particular, the development of the crystal filter has had a considerable effect on the design of multi-channel carrier systems of the type installed on the London–Birmingham coaxial cable.

CRYSTAL-OSCILLATOR APPLICATIONS

In considering frequency-generator applications it can be assumed that quartz control provides the simplest solution when a specific frequency in the range 50–200 000 kc./s. of stability better than $\pm 100/10^6$ is required, and almost the only solution for stabilities better than $\pm 10/10^6$.

The achievement of the international tolerances for fixed radio transmitters of frequencies greater than 50 kc./s. is readily accomplished with the crystal oscillator. Considering three types of Post Office transmitters operating on the fixed frequencies 484, 18 010 and 70 400 kc./s. respectively, the control is obtained with low-power crystal oscillators of fundamental frequencies 484, 4 502·5 and 17 600 kc./s., the carriers for the two higher frequencies being obtained with frequency doublers, and the required radio-frequency power with amplifiers in each case. The frequency/temperature coefficients of the crystals are less than $\pm 1/10^6$ per degree C., and no difficulty is experienced in maintaining the transmitters within the prescribed tolerances.

In common-wave operation—several transmitters operating on the same frequency—which is a feature of present-day broadcasting, the carriers of the several transmitters may not vary mutually by more than a small fraction of 1 c./s., otherwise the transmission quality will suffer. Thus on a frequency of 767 kc./s. the carrier stability must be better than $1/10^7$ over long periods. The crystal oscillator enables this high performance to be met.

A frequency standard is an essential part of the equipment of any telecommunication development laboratory, and whereas the limitations of a valve-maintained fork standard become apparent for stabilities better than $\pm 1/10^7$, the crystal enables a stability approaching $\pm 1/10^8$ to be achieved.

The high order of carrier stability necessary on a multi-channel carrier system of the type installed by the Department, in which "send" and "receive" carriers may not differ by more than a few cycles, is obtained by crystal control. Considering the London–Birmingham system operating on the C.C.I.F. frequencies, at the transmitting end each group of 12 audio circuits is translated to the band 60–108 kc./s., and each five of these groups is transferred to the band 312–552 kc./s., eight of them being accommodated in the band 564–2 540 kc./s. for transmission on the coaxial cable, the reverse process being performed at the receiving end. The carrier series at the two terminals are derived from a crystal oscillator arranged to control the frequencies of multipliers and dividers designed to produce the required harmonic series, the synchronizing signal for the remote terminal being transmitted as a pilot on the cable.

There are numerous other applications of the crystal oscillator, e.g. fixed-frequency receivers, but those given are representative and clearly illustrate the importance of the crystal as an oscillation generator in both radio and cable communication systems.

CRYSTAL-RESONATOR APPLICATIONS

The selection of a speech channel becomes increasingly difficult as the carrier frequency is progressively raised and, whereas the filter employing electrical circuits is suitable for use on audio frequencies, the comparatively high losses of the best electrical circuits more or less preclude their use for channel selection at radio frequency where the percentage band width required becomes very small. Owing to its low dissipation, however, the quartz crystal is particularly suited for radio frequencies, and the filter employing crystal-resonator elements is now commonly used in telecommunication. The band width which may be obtained with a filter employing only crystal elements is somewhat limited by virtue of the limits of the ratio C/C_1 of the equivalent circuit, Fig. 1, but with the aid of capacitors and inductors band widths up to 13·5 % are realized.

One of the most recent applications of the crystal filter is to multi-channel carrier systems, the selector of the upper sideband after the first modulation and the final demodulation being accomplished with filters employing crystal elements. In addition, they are used for the selection of the carriers from the harmonic generators for the first and second stages of frequency translation. The channel filter employs eight and the carrier filter four X-cut resonators. Another interesting application is in the selection at the second intermediate frequency of the two channels and the vestigial carrier in a receiver designed for single-sideband two-channel operation.

PRODUCTION OF QUARTZ OSCILLATORS AND RESONATORS

Quartz crystallizes in two forms, the structure of one being a mirror image of the other and the two being known as right- and left-hand crystals. The crystals are found in all parts of the world, but the chief source of good material

is Brazil. Very few possess the ideal shape. A good specimen weighs 1 to 5 kg. Despite its irregular form, the quartz crystal possesses its own set of interfacial angles, which are constant for all specimens; thus the angle between adjacent prism faces is 120° and between pyramid faces and the perpendicular to the Z axis is 51° 47′.

Lack of homogeneity of the structure is referred to as "twinning," of which quartz is subject to three types: "electrical," in which adjacent parts develop their electric axes in opposite senses; "optical," in which a single crystal comprises the structure associated with both left-hand and right-hand crystals; and "combined" twinning, which is a combination of both optical and electrical. Extensive twinning in a crystal normally precludes its use for the piezo-electric application, and as almost all crystals are twinned to an extent which may only be determined after the crystal has been cut, the selection of the material presents a very difficult problem. Optical and chemical tests for twinning are made on the crystals throughout the production process.

In the bulk production of oscillators and resonators, the plate orientation to the crystallographic axes must agree with the specified value within very narrow limits. With well-formed crystals, the accuracy may often be achieved by reference to the natural faces, but with the majority of crystals it is necessary to have recourse to optical methods.

The hardness of quartz is such that the only suitable cutting material is diamond; a special machine has therefore been designed for precision cutting. The cutter is a diamond-charged metal disc, and the work is automatically fed to the saw. The preliminary lapping of the cut slices to specified dimensions is accomplished with rotary laps. Up to this stage, bulk production-methods have been employed, but it is now necessary to operate on each blank individually and to test the crystal at each stage of the work, the oscillators in drive circuits which are replicas of the final circuit and the resonators in response measuring-sets. In the process, the frequency-determining dimension is adjusted in discrete steps to the specified value, the necessary confirmatory frequency measurements being carried out after each adjustment. The precise adjustment of the crystal is a very skilled operation; a high order of manipulative skill is called for, and success is achieved only after considerable experience.

To ensure constancy of the equivalent circuit, it is necessary that the electrodes of filter resonators be placed in intimate contact with the crystal surfaces. Two methods are commonly practised; the one is the sputtering process, in which gold films are deposited, and the other is the evaporating process, whereby aluminium is deposited on the crystal faces.

FUTURE DEVELOPMENTS IN APPLICATIONS AND PRODUCTION

The author visualizes that the quartz crystal will play an increasingly important part in the ever-growing communication network. The natural tightening of the permissible tolerances for radio transmitters will force the designer to use crystal oscillators wherever possible, while the success of the resonator in the filter application has ensured its large-scale use in future multi-channel carrier systems.

The advent of the low-frequency/temperature coefficient crystal has rendered temperature control unnecessary, except for the highest stabilities, but it is anticipated that further advances will be made towards the achievement of a true zero coefficient over a very wide temperature range. Crystal frequency-standards stable to better than 1 part in 10^8 over long periods will soon be available and the crystal-controlled clock will form an essential part of the astronomer's equipment.

Considering production, future developments will be concerned mainly with speeding-up manufacture and with the more economical use of quartz. The former will be accomplished by using ganged saws and by the introduction of automatic lapping equipment, and the latter by using plates containing the maximum permissible amount of twinning and by developing economical methods for dealing with waterworn and other imperfect raw crystal.

EDDY-CURRENT LOSSES IN MULTI-CORE PAPER-INSULATED LEAD-COVERED CABLES, ARMOURED AND UNARMOURED, CARRYING BALANCED 3-PHASE CURRENT

By A. H. M. ARNOLD, Ph.D., D.Eng., Associate Member.*

(ABSTRACT *of an official communication from the British Electrical and Allied Industries Research Association which will be published in February in Part II of the Journal.*)

LIST OF SYMBOLS

All quantities are in c.g.s. units.

R = Direct-current resistance of each conductor per centimetre length.

R' = Alternating-current resistance of each conductor per centimetre length.

(In the case of the four-core cable with one conductor not loaded, the symbol R' is used to denote the average value of the alternating-current resistance of the three current-carrying conductors.)

* National Physical Laboratory.

LIST OF SYMBOLS—*continued.*

R_s = Direct-current resistance of lead sheath per centimetre length.

R_a = Direct-current resistance of armouring per centimetre length.

I = Direct current or r.m.s. alternating current in each current-carrying conductor.

P = Power loss per centimetre length in conductor with direct current.

P' = Power loss per centimetre length in conductor with alternating current, including the power supplied from that conductor to provide the eddy-current losses in neighbouring conducting material.

LIST OF SYMBOLS—*continued.*

P_s = Power loss per centimetre length in sheath due to eddy currents.
A = Cross-sectional area of conductor, in square centimetres.
(The area is the actual area of conducting material.)
A_s = Cross-sectional area of lead sheath, in square centimetres.
f = Frequency, in cycles per second.
$\omega = 2\pi f$.
σ = Conductivity of conductor.
σ_s = Conductivity of lead sheath.
$k = \dfrac{\text{Conductivity across strands of conductor}}{\text{Conductivity along strands of conductor}}$
(The value of k is different for different conductors, but for the conductors of an impregnated cable a value of 0·8 is indicated by the experimental evidence at present available.)
$x^2 = 4\omega/R = 8\pi f\sigma A$.
$x_1^2 = kx^2$.
$x_s^2 = 4\omega/R_s = 8\pi f\sigma_s A_s$.
$x_a^2 = 4\omega/R_a$.
N = Number of strands in each conductor.
d_1 = Diameter of strands in each conductor.
d = Effective diameter of conductor $= d_1\sqrt{\{(4N-1)/3\}}$
(In the case of conductors of circular cross-section the effective diameter is equal to the actual diameter.)
s = Thickness of insulation between conductors.
d_s = External diameter of lead sheath.
t_s = Thickness of lead sheath.
t_i = Thickness of insulation between conductor and lead sheath.
d_a = External diameter of armouring.
t_a = Diameter of armour wires.
$\alpha = d/(d+s)$.
$\beta = (d_s - 2t_s - 2t_i)/(d_s - t_s)$.
$\gamma = (d_s - 2t_s - 2t_i)/(d_a - t_a)$.
$J_n(xj\sqrt{j})$ = Bessel function of order n and argument $xj\sqrt{j}$.
$\rho_n = -\dfrac{J_{n+1}(xj\sqrt{j})}{J_{n-1}(xj\sqrt{j})} = -\phi_n + j\psi_n$.
$F(x) = \frac{1}{8}x^2\psi_2$.
$G(x) = \frac{1}{8}x^2\psi_1$.
$H(x) = F(x)/G(x) = \psi_2/\psi_1$.
$F(x_1)$, $G(x_1)$ and $H(x_1)$ are corresponding functions of x_1.
λ_0 = Skin effect.
λ_p = Proximity effect.
λ_s = Lead-sheath effect.
λ_a = Armouring effect.

INTRODUCTION

It is well known that the effective resistance of a conductor to the passage of an alternating current is greater than the resistance of the same conductor to the passage of direct current, on account of induced currents in the conductor and in neighbouring conducting material.

In symbolic form—

Power dissipated in conductor with direct current of magnitude $I = P = RI^2$ . . . (1)

Power dissipated in conductor with alternating current of r.m.s. value equal to $I = P' = R'I^2$ . . . . (2)

Provided that no magnetic material is present in the field neither R nor R' is directly dependent on the magnitude of the current, although both may be indirectly affected in so far as the heating effect of the current alters the physical condition of the conductor. It is convenient, therefore, to consider only the ratio of the losses in the two cases. Dividing equation (2) by equation (1)—

$$P'/P = R'/R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

In the case of a multi-core cable with a lead sheath and armouring the difference between the value of R'/R and unity may be conveniently split into four parts as in equation (4)—

$$\frac{R'}{R} = 1 + \lambda_0 + \lambda_p + \lambda_s + \lambda_a \quad . \quad . \quad . \quad (4)$$

λ_0 is the difference between R'/R and unity for a conductor remote from all other conductors or conducting material, and is usually known as the skin effect.

λ_p is the additional increment of R'/R due to the presence of the other conductors of the cable, and is usually known as the proximity effect.

λ_s is the additional increment of R'/R due to the presence of the lead sheath, and will be termed the lead-sheath effect.

λ_a is the additional increment of R'/R due to the presence of the armouring, and will be termed the armouring effect.

λ_0, λ_p and λ_s are independent of the value of the current in the conductor, except in so far as the value of R is affected by the heating effect of the current.

λ_a is dependent on the value of the current, but where all the conductors of the system are combined in a single cable, the variation of λ_a with current is small and little error is involved in assuming λ_a to be independent of the value of the current. Equation (4) may be used for unarmoured cables if the value of λ_a is assumed to be equal to zero.

In this report formulae are developed for determining the values of λ_0, λ_p, λ_s and λ_a for multi-core lead-covered armoured and unarmoured cables of the following types, when carrying balanced three-phase currents in three conductors:—

(*a*) Three-core cable with conductors of circular cross-section.
(*b*) Three-core cable with conductors of segmental cross-section.
(*c*) Four-core cable with conductors of segmental cross-section.

Experimental results are given which show that these formulae are reasonably accurate within the range of cable sizes and frequencies at present in use.

SKIN EFFECT

The well-established formula for the skin effect in an isolated solid conductor of circular cross-section may be used for stranded conductors of circular or segmental cross-section without serious error. This formula is

$$\lambda_0 = F(x) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where the function $F(x)$ is tabulated in Table 1.

TABLE 1

The Functions $F(x)$, $G(x)$ AND $H(x)$

x	$F(x)$	$G(x)$	$H(x)$	x	$F(x)$	(Gx)	(Hx)
0·0	0·000	0·000	0·333				
0·5	0·000	0·001	0·334	3·1	0·351	0·425	0·826
0·6	0·001	0·002	0·334	3·2	0·385	0·444	0·867
0·7	0·001	0·004	0·335	3·3	0·420	0·463	0·908
0·8	0·002	0·006	0·337	3·4	0·456	0·481	0·948
0·9	0·003	0·010	0·339	3·5	0·492	0·499	0·987
1·0	0·005	0·015	0·341				
1·1	0·008	0·022	0·345	3·6	0·529	0·516	1·025
1·2	0·011	0·031	0·350	3·7	0·566	0·533	1·061
1·3	0·015	0·041	0·356	3·8	0·603	0·550	1·096
1·4	0·020	0·054	0·364	3·9	0·640	0·567	1·129
1·5	0·026	0·069	0·373	4·0	0·678	0·584	1·160
1·6	0·033	0·086	0·385	4·1	0·715	0·601	1·190
1·7	0·042	0·106	0·399	4·2	0·752	0·618	1·218
1·8	0·052	0·126	0·414	4·3	0·789	0·635	1·243
1·9	0·064	0·149	0·433	4·4	0·826	0·652	1·267
2·0	0·078	0·172	0·454	4·5	0·863	0·669	1·290
2·1	0·094	0·197	0·477	4·6	0·899	0·686	1·311
2·2	0·111	0·221	0·503	4·7	0·935	0·703	1·330
2·3	0·131	0·246	0·531	4·8	0·971	0·720	1·348
2·4	0·152	0·271	0·562	4·9	1·007	0·738	1·365
2·5	0·175	0·295	0·595	5·0	1·043	0·755	1·381
2·6	0·201	0·318	0·630				
2·7	0·228	0·341	0·667				
2·8	0·256	0·363	0·705				
2·9	0·286	0·384	0·745				
3·0	0·318	0·405	0·785				

Above $x = 5$,

$$F(x) = \frac{x}{2\sqrt{2}}\left(1 + \frac{3}{8x^2}\right) - \frac{3}{4}$$

$$G(x) = \frac{x}{4\sqrt{2}}\left(1 + \frac{1}{8x^2}\right) - \frac{1}{8}$$

PROXIMITY EFFECT

Semi-empirical solutions for the proximity effect in 3-phase systems of stranded conductors may be developed from J. C. Costello's formal solution* for a 3-phase system of solid conductors of circular cross-section and from experimental results given in the paper. These solutions, which are given below, may be considered to be valid for all values of the argument x less than 3.

For stranded conductors of circular cross-section, in a system of 3 conductors arranged symmetrically, and carrying balanced 3-phase currents,

$$\lambda_p = \frac{3}{2}\alpha^2 G(x_1) \Big/ \left\{1 - \frac{5}{24}\alpha^2 H(x_1)\right\} \quad . \quad . \quad (6)$$

For stranded segmental conductors in a system of 3 conductors arranged symmetrically, and carrying balanced 3-phase currents,

$$\lambda_p = \frac{5}{4}\alpha^2 G(x_1) \Big/ \left\{1 - \frac{5}{24}\alpha^2 H(x_1)\right\} \quad . \quad . \quad (7)$$

For stranded segmental conductors in a system of 4 conductors arranged symmetrically, and carrying balanced 3-phase currents, the average proximity effect in the 3 current-carrying conductors is given by equation (8), namely

$$\lambda_p = \alpha^2 G(x_1) \Big/ \left\{1 - \frac{4}{5}\alpha^2 H(x_1)\right\} \quad . \quad . \quad . \quad (8)$$

The functions $G(x_1)$ and $H(x_1)$ are the same functions as the functions $G(x)$ and $H(x)$ tabulated in Table 1, but with the argument x_1 instead of x.

* J. C. COSTELLO: *Journal I.E.E.*, 1936, 79, p. 595.

LEAD-SHEATH EFFECT

Semi-empirical solutions for the lead-sheath effect may be developed from F. W. Carter's formal solution* for the loss in a thin sheath caused by 3-phase balanced currents flowing in conductors of negligibly small section arranged symmetrically within the sheath and from experimental results given in the paper. These solutions are given below.

For stranded conductors of circular cross-section, in a

* F. W. CARTER: *Proceedings of the Cambridge Philosophical Society*, 1927 23, p. 901.

system of 3 conductors arranged symmetrically, and carrying balanced 3-phase currents,

$$\lambda_s = \frac{x_s^2 x^2\left[\dfrac{2(d+s)}{\sqrt{3}(d_s - t_s)}\right]^2}{5\left(1+\dfrac{1}{16}x_s^4\right)\left(1+\lambda_p\right)^{\frac{1}{2}}} \quad . \quad . \quad . \quad (9)$$

where λ_p is given by equation (6).

For stranded segmental conductors in a system of 3 conductors arranged symmetrically, and carrying balanced 3-phase currents,

$$\lambda_s = \frac{5\beta^2 x^2 x_s^2}{86\left(1+\dfrac{1}{16}x_s^4\right)\left(1+\lambda_p\right)^{\frac{1}{2}}} \quad . \quad . \quad (10)$$

where λ_p is given by equation (7).

For stranded segmental conductors in a system of 4 conductors arranged symmetrically, and carrying balanced 3-phase currents in 3 conductors,

$$\lambda_s = \frac{5\beta^2 x^2 x_s^2}{79\left(1+\dfrac{1}{16}x_s^4\right)\left(1+\lambda_p\right)^{\frac{1}{2}}} \quad . \quad . \quad (11)$$

where λ_p is given by equation (8).

ARMOURING EFFECT

In a similar manner to the development of formulae for the lead-sheath effect, semi-empirical formulae, given below, may be developed for the armouring effect.

For stranded conductors of circular cross-section, in a system of 3 conductors arranged symmetrically, and carrying balanced 3-phase currents,

$$\lambda_a = \frac{x^2 x_a^2\left[\dfrac{2(d+s)}{\sqrt{3}(d_a - t_a)}\right]^2}{\left(1+\dfrac{13}{16}x_a^4\right)\left(1+\lambda_p\right)^{\frac{1}{2}}} \quad . \quad . \quad . \quad (12)$$

where λ_p is given by equation (6).

For stranded segmental conductors in a system of 3 conductors arranged symmetrically, and carrying balanced 3-phase currents,

$$\lambda_a = \frac{25\gamma^2 x^2 x_a^2}{86\left[1+\dfrac{13}{16}x_a^4\right]\left[1+\lambda_p\right]^{\frac{1}{2}}} \quad . \quad . \quad (13)$$

where λ_p is given by equation (7).

For stranded segmental conductors in a system of 4 conductors arranged symmetrically, and carrying balanced 3-phase currents in 3 conductors,

$$\lambda_a = \frac{25\gamma^2 x^2 x_a^2}{79\left[1+\dfrac{13}{16}x_a^4\right]\left[1+\lambda_p\right]^{\frac{1}{2}}} \quad . \quad . \quad (14)$$

where λ_p is given by equation (8).

NOTE ON ARMOUR LOSS IN MULTI-CORE CABLES

By S. WHITEHEAD, M.A., Ph.D., Member.*

(ABSTRACT *of a paper which will be published in February in Part II of the Journal.*)

The formulae for the armour loss in multi-core cables, already derived in a recent paper,† may be expressed more accurately by including more terms in the series for the hysteresis loss. The results may also be applied to cables in steel pipes and tubes.

Let c = axial displacement of conductor from cable axis, in cm.; b = mean radius of armour, in cm.; A = volume of armour, in cm^3 per cm. length of cable; ρ = resistivity of armour, in microhm-cm.; $R_A = \rho/A$; $\delta = A/(2\pi b)$; μ = permeability and η = hysteresis constant of armour material.

The armour loss is made up of the eddy-current loss P_e and the hysteresis loss P_h.

$$P_e = \left(\frac{c}{b}\right)^2 \frac{9\cdot 6\, R_A}{1 + 10\cdot 15 R_A^2}$$

microwatts per cm. per (amp.)^2 for a 3-core cable at 50 c./s.

$$P_e = \left(\frac{c}{b}\right)^2\left[1+\frac{1}{4}\left(\frac{c}{b}\right)^2\right]\frac{8R_A}{1+10\cdot 15R_A^2}$$

for a twin cable at 50 c./s.

$$P_h = 18A\eta\left[\frac{0\cdot 3\mu}{b}\left(\frac{c}{b}\right)\frac{1}{1+(\mu\delta/2b)}\right]^2$$

microwatts per cm. per (amp.)^2 for a 3-core cable at 50 c./s.

$$P_h = 12A\eta\left[\frac{0\cdot 4\mu}{b}\left(\frac{c}{b}\right)\frac{1}{1+(\mu\delta/2b)}\right]^2$$

for a twin cable at 50 c./s.

The preceding formulae may be applied to various frequencies by correcting P_e according to the well-known general formulae given in the original paper, and P_h by the fact that it is proportional to frequency. At higher frequencies the screening effect of the sheath currents is appreciable and may be allowed for by dividing by $(1 + m^2)$, where $m = \omega/(1\,000\, R_s)$ and R_s is the sheath

* British Electrical and Allied Industries Research Association.

† S. WHITEHEAD and E. E. HUTCHINGS: *Journal I.E.E.*, 1938, 83, p. 517.

resistance in microhm/cm. For wire armour η was shown to be 0·001 and μ to be 300 in the original paper, but an upper limit for μ of 5 000 was suggested for steel tape, which, however, makes very little difference for the standard thicknesses of steel tape. Later evidence on pipes and thin tapes has shown that μ should be taken as 300 both for wires and for tapes.

With these corrections, satisfactory agreement has been obtained with the measurements of Dr. Arnold, reported elsewhere,* and with evidence in other connections which has recently come to hand.

Some transcription errors in the original paper are also corrected in the complete Note.

* See page 56.

BROADCAST RECEIVERS: A REVIEW

By N. M. Rust,* O. E. Keall,* J. F. Ramsay, M.A.,* and K. R. Sturley, Ph.D., Associate Member.*

(Abstract *of a paper which will be published in June in Part III of the Journal.*)

This paper, consisting of two main Parts, is a review of broadcast receiver circuits and developments over the period 1929 to 1939, a decade of intense activity terminated by the outbreak of war.

PART 1. REVIEW OF CIRCUITS

The first Part, devoted to an examination of circuits which have withstood the test of production, takes the more popular superheterodyne receiver as a model, and analyses the circuit stage by stage from aerial input to audio-frequency output. Accessory technical features, automatic frequency correction, remote control, etc., are also discussed in relation to illustrative diagrams. Three popular types of receiver are depicted, viz. the general purpose 4-valve superheterodyne receiver with "preset coil" push-button tuning, the local-station tuned radio-frequency 3-valve receiver and the all-wave 5-valve superheterodyne with a radio-frequency stage.

In retrospect it would appear that as the sales market has consisted mainly of purchasers of first receivers, the trend of design has been influenced by selling points rather than basic principles and potential user's needs.

The Part ends by discussing two specifications which attempt to define and assess the performance of receivers, the first in 1930, later modified and considerably extended ("Standards on Radio Receivers 1938") by the committee of the Institute of Radio Engineers, and the second in this country in 1936 by the Radio Manufacturers Association ("Specification for the Testing and Expressing Overall Performance of Radio Broadcast Receivers").

PART 2. FUNDAMENTAL PROBLEMS AND FUTURE DEVELOPMENTS

The second Part of the paper is devoted to an examination of the special problems which confront the receiver designer. The problems are considered under the headings of selectivity, fidelity, electrical interference, automatic and remote control of signals, performance specification in relation to interference protection, and wavelength allocation.

Selectivity. In considering selectivity it has been assumed that transmitters do not radiate sidebands outside the audio spectrum. A chart representing day and night field-strengths in London of medium-wave and long-wave transmitters under the proposed Montreux Plan indicates that in a general-purpose receiver a pass band of $\pm$ 3 kc./s. is necessary in order to avoid serious interference. Although selective circuits are preferably positioned prior to the frequency-changer this is not economically possible. The desirable attenuation characteristic of the intermediate-frequency selective circuits is discussed at length and circuits capable of fulfilling this requirement are described. The need for variable selectivity is stressed. Some of the advantages of the homodyne (reinforced carrier) receiver are pointed out and valve non-linearity is considered in relation to selectivity.

Fidelity. The three important electrical aspects of fidelity are distortion, frequency response and contrast (variation in volume between loud and soft passages). Distortion is determined less by total harmonic percentage than by the percentage of the high harmonics. Inharmonic frequencies are produced by the same process as the higher harmonics, and it is these that are detrimental to musical quality. An overall audio-frequency response capable of variation is necessary if correct aural balance is to be preserved for different volume-control settings and positions of the listener in relation to the loud-speaker. Adjustment of the tonal balance at the listening position would therefore seem to be a desirable feature. Full contrast cannot be radiated by the transmitter and some compression of the "pp" and "ff" passages is inevitable. This could be overcome by automatic compression at the transmitter with correctly related expansion at the receiver, but it is not feasible unless all receivers have this modification. Binaural or stereophonic broadcasting has not yet received much attention.

High fidelity can, under existing conditions, be approached only by transmission on ultra-short waves, and developments are likely to occur with amplitude-modulated and frequency-modulated ultra-short-wave transmissions. The latter system, pioneered by Armstrong, has the particular advantage of giving a signal/noise ratio higher than that for the former at the expense of an increased intelligence spectrum.

Electrical Interference. Interference from electrical equipment offers a serious obstacle to the realization of high fidelity, and its suppression is now regarded as of vital importance to the designer and the user of a receiver. The most obvious method of improvement is to suppress the

* Marconi's Wireless Telegraph Company, Ltd.

radiation of the disturbances at their source, for most interference is transmitted via the power lines, but the position is likely to remain unsatisfactory until legislation is introduced making this compulsory. The listener can, to some extent, mitigate interference effects by increasing the aerial efficiency or by employing a noise-limiting circuit which reduces receiver gain during noise pulses. The first system employs special aerial and/or feeder arrangements. Either a special aerial, usually a frame or single or multiple dipole, is employed to differentiate between the signal and interference fields, or the aerial is removed from the immediate neighbourhood of the interference field and is connected to the receiver by twisted, screened twin or concentric feeder in which induced interference voltages are cancelled or eliminated.

Noise-limiting systems have proved useful for reducing the effect of certain types of interference, e.g. that due to car ignition, but they are liable to involve distortion of the desired signal. They have so far not been applied to broadcast receivers.

Automatic Control of Signals. Automatic control can be applied to almost every manually-controlled function or action, and it is usually more difficult to decide on the economic value of a control than to devise new methods of achieving it. Three important examples of a change-over to automatic control with a view to improved operation are automatic volume control (appreciably reducing output variations due to rapid and often large changes of input signal), automatic frequency correction and automatic selectivity control. Considerable changes in automatic volume-control methods are not likely, but developments may be expected in methods of automatic frequency-correction and selectivity.

Automatic frequency-correction may be used with push-button, motor or manually-operated tuning, to correct for errors in the intermediate frequency arising from inaccurate oscillator tuning-setting or oscillator frequency-drift. Recent developments have led to a more economical use of circuit components in attaining a given degree of control. The two units of an automatic frequency-control system are the discriminator or error detector, translating intermediate-frequency error into a control voltage, and the control device providing frequency correction of the oscillator in the correct sense. The overall performance of the units is dependent mainly upon that of the discriminator, and developments are taking place which aim at increasing the control accuracy and reducing the tuning range over which the transmission is held. A large range is undesirable because it causes a number of stations on either side of a powerful station to be skipped when retuning. One of the most satisfactory forms of control is the motor-operated control condenser, the direction and travel of the motor being controlled by the discriminator output voltage, but on account of cost it is used only on commercial telegraph services. For broadcast receivers it is usual to employ in parallel with the oscillator circuit a valve simulating a reactance the value of which is dependent upon the discriminator control voltage applied to its grid. A recently developed device having the merit of extreme simplicity and reasonable sensitivity is a condenser, the capacitance of which is controlled by a d.c. polarizing voltage. One electrode is a flat aluminium plate having a thin polished anodized surface; the other is a thin leaf of polished aluminium foil lying flat on the anodized surface of the first electrode. Changes of a d.c. polarizing voltage applied to the electrodes by the discriminator voltage cause attraction or repulsion of the aluminium foil and so change the capacitance.

Automatic selectivity control may be effected by variation of the audio-frequency pass range, particularly in the homodyne receiver, by means dependent on carrier amplitude, or noise and interference output. Valves simulating capacitances or polarized condensers may be used to reduce the audio-response range. Alternatively, control of selectivity may be realized in the intermediate-frequency stages and a circuit is described comprising a discriminator, responsive to an adjacent interfering carrier or carriers, and operating control devices, such as polarized condensers, to displace the pass band away from the interfering carrier or when two carriers are present to contract the pass band symmetrically. Experimental work on the relation between desirable pass-band and input signal strength is described.

Remote Control. The advisability of complete control of receiver functions at the listening point has been stressed under the heading "Fidelity" so that, ideally, remote control should include selectivity, volume, tone control and on-off switching as well as tuning. In certain types of push-button receivers, notably with motor-controlled tuning, remote control is possible merely by extension of the push-button switch leads to switches at the control points. A system, using the reactance and standing-wave properties of radio-frequency cables, has been developed and push-button or continuous tuning control, which is effective over distances of 10 ft. on short-wave bands and as much as 100 ft. on medium and long waves, can be obtained with the multi-wire radio-frequency cable now available. Circuits are described in which remote selectivity control is possible by varying a condenser (at the listening point) which forms a bottom capacitance coupling between the intermediate-frequency tuning circuits. Volume and tone control can be obtained by a remote potentiometer and shunt capacitances inserted between the detector and the audio-frequency amplifier. On-off switching is most easily obtained by running screened supply wires to a switch in the remote unit. All the above functions may be carried out with an 8-wire cable, but by omitting on-off switching and variable selectivity four wires only are necessary. The distances cited above may be exceeded if the cables be treated as transmission lines rather than as capacitances.

Performance Specifications. It is considered that a performance specification should be of a form which allows the user to assess the merits of the receiver under actual operating conditions. Detailed measurements relating to any particular technical feature are of secondary importance in comparison with measurements directed towards determining under what conditions a receiver can provide an output of the required form at a specified level, with specified signal-to-noise and signal-to-interference ratios.

Modifications to the existing specifications can provide results of greater value to the user. For example, it is desirable to assess the sensitivity of broadcast receivers on a basis of signal-to-noise ratio, for clearly high sensitivity is of no value if accompanied by a noise output comparable with the standard output. Experiment indi-

cates that the signal input necessary to produce standard output with a signal-to-noise ratio of 15 db. provides a reasonable basis for receiver comparison. Selectivity, on the other hand, presents much more difficulty, particularly as there is no generally accepted definition. Furthermore, it is not often a criterion of performance under service conditions, for the transmitter characteristics may have far more important consequences than receiver characteristics. Recent experiments on interference effects in receivers have shown that the part played by the transmitter characteristics is far more important than any cross-modulation and distortion effects in the receiver itself. Four specially-designed receivers, viz. homodyne, straight radio-frequency of four stages, single-span superheterodyne, superheterodyne with highly selective radio-frequency and intermediate-frequency stages, showed that similar performance resulted for constant audio-frequency band width, the major cause of interference being sideband splash, which completely masked any non-linear effects in the receivers themselves. A variety of tests are described which show that, apart from interference due to fundamental sidebands causing equivalent modulation to a depth well in excess of 100% on a weak station adjacent to a strong one, serious interference may occur due to harmonic sidebands when two such stations are separated by several channels. Tables and charts show the order of interference to be expected, as well as the carrier separation necessary to avoid interference under selected conditions. It is concluded that existing forms of selectivity measurement have only a design value and bear little relation to performance in service, and that under present conditions it is not possible to put forward a method of measurement by which performance in relation to interference may be assessed, since interference production must be considered to be a characteristic involving the transmitter as well as the receiver.

Wavelength Allocation as a Means of Improving Reception Conditions. The large number of broadcasting stations operating on medium-wave and long-wave bands has necessitated international collaboration on the allocation of wavelengths, and the latest agreement, the Montreux Wavelength Plan, is generally regarded as a good compromise. The urge to use other means of broadcasting (relaying over a wired system) is being intensified by the technical limitations imposed by the congestion on medium and long waves.

One possible solution should be mentioned, and this is to use "group allocation" of wavelengths. Under the Montreux Plan, Great Britain has exclusive use (as far as Western Europe is concerned) of 12 wavelengths in the medium-wave band. These occupy a nominal frequency spectrum of 108 kc./s., but, in actual practice, sideband overlap into adjacent channels causes difficulties in the reception of adjacent stations.

A distribution of sideband width in accordance with the programme requirements would be possible if, instead of 12 separated channels of 9 kc./s. nominal width, the actual spectrum of 108 kc./s. were divided into two bands, one towards the high-frequency and the other towards the low-frequency end of the range. Thus 5 kc./s. single-sideband transmission could be allotted for speech and 20 kc./s. double-sideband for programmes requiring high quality. Each band would provide any required combination between the limits of 21 speech and two high-fidelity channels. Transmitter and receiver design would need to be correlated; no sidebands should be radiated outside the transmission channel and the receiver should select only the spectrum necessary for the desired programme. Careful geographical distribution of the various transmitters would also assist.

For a given total frequency spectrum allotted to a country, group allocation permits the most economical programme-frequency distribution and goes far towards the elimination of station interference if the conditions for transmitter and receiver design cited above are fulfilled. Immediate general acceptance of the principle is unlikely owing to the special technical problems involved, but future developments along these lines are possible.

DISCHARGES IN INSULATION UNDER ALTERNATING-CURRENT STRESSES

By A. E. W. Austen, B.Sc., Ph.D., and S. Whitehead, M.A., Ph.D., Member.

[Abstract *of a paper which will be published in Part II (April) and also in Part III (March) of the Journal.*]

If the amplified voltage from the detector terminals of a Schering bridge is applied to the X plates of an oscillograph, while a voltage derived from the supply voltage is applied to the Y plates of the oscillograph, then the bridge is balanced when the oscillograph shows a horizontal straight line. If the phase of the voltage of the Y plates is suitably adjusted a change in the capacitance of the specimen causes a tilting of this line, while a change in power factor produces an ellipse of which the vertical diameter gives the magnitude of the change. A change both of capacitance and of power factor gives an ellipse with a tilted axis. Typical figures are shown in Fig. 1.

When the specimen is a heterogeneous dielectric and when the electric stress is raised beyond a certain value, vertical kicks appear in the trace and eventually the figure is distorted (Fig. 2). Individual cycles of voltage may be examined by applying a vertical time-sweep. The phenomena are too complex for quantitative analysis but appear consistent with the hypothesis that voids or inclusions in the dielectric discharge when the voltages across them exceed certain values.

A simplified model is shown in Fig. 3(a). The condenser C_c together with the two grid-controlled gas discharge tubes represents a portion of the dielectric which discharges when the voltage across it is outside the limits $+U_0$ and $-U_0$. When discharges take place the voltage is reduced in a short time Δt to $+U_1$ and $-U_1'$ respectively.

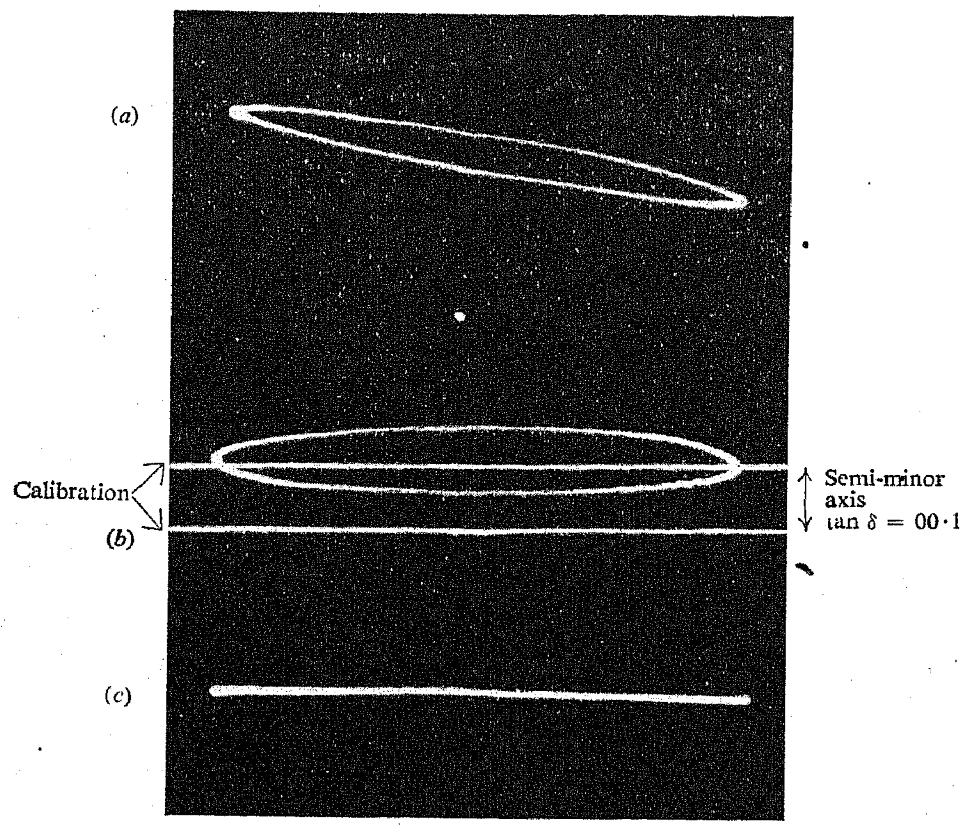

Fig. 1
(a) Both components unbalanced.
(b) Phase angle unbalanced only.
(c) Bridge balanced.

In the absence of discharges the voltage v across C_c is a constant fraction of the total applied voltage

$$v = \lambda V_0 \cos \omega t, \text{ where } \lambda = C_b/C_c + C_b$$

and in the intervals between discharges the variation of v remains the same but starts from the extinction voltage U_1 (or $- U_1'$), i.e.

$$v = U_1 + \lambda V_0 \cos \omega t.$$

Thus if a positive discharge occurs it will be followed by a second positive discharge when the voltage has increased by an amount $U_0 - U_1$, and so on until the increment of voltage between extinction and the voltage crest is less than this value. A negative discharge will then occur when the voltage has decreased by $U_1 + U_0$, and so on.

Accordingly the epochs on the wave at which discharges occur can be represented on the line diagram (Fig. 4), where ΔV, the change in applied voltage during Δt, varies with the epoch on the wave at which it occurs.

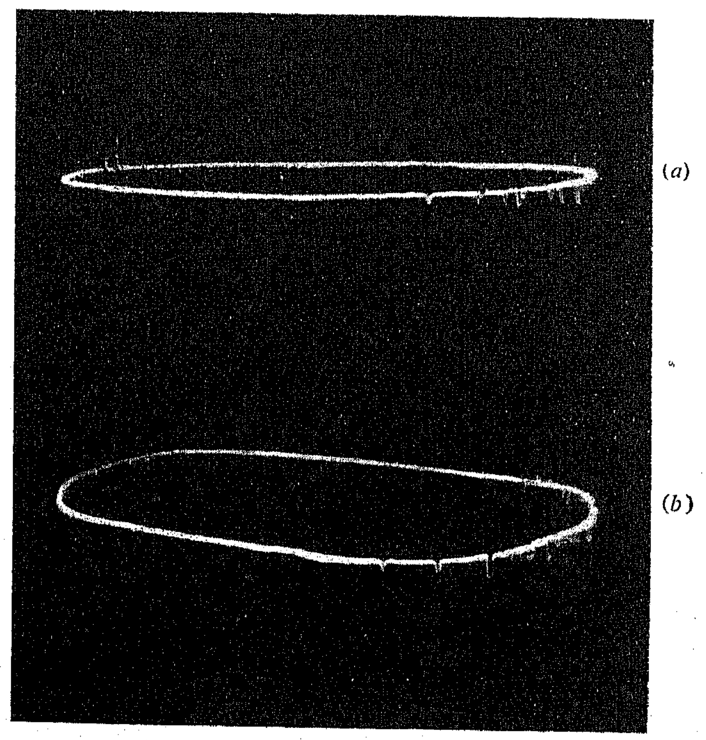

Fig. 2.—Ionization in oil-impregnated paper.
(a) 8 kV per mm. (b) 20 kV per mm.

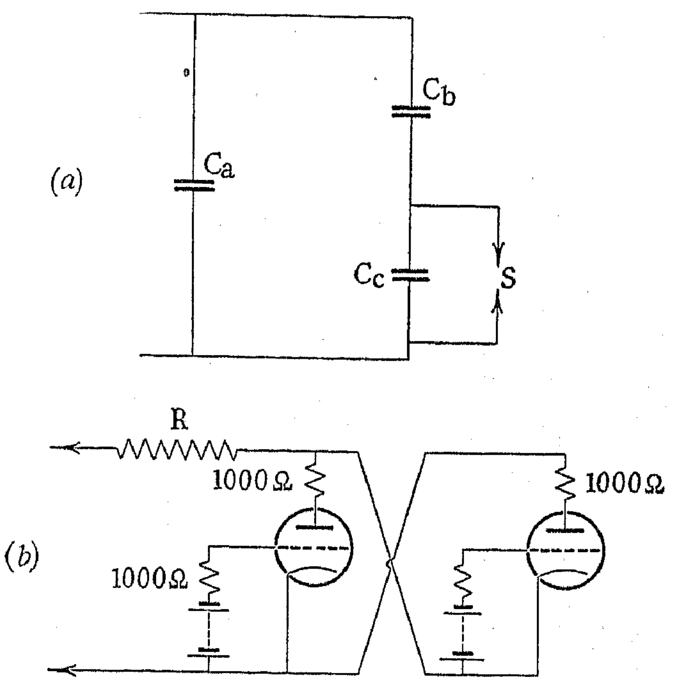

Fig. 3
(a) Model circuit representing dielectric with void at one end.
(b) Pair of thyratrons as artificial spark-gap.

In the absence of surges no discharge will occur until $\lambda V_0 = U_0$, when a discharge will occur at a voltage crest (e.g. a positive crest). The next discharge will occur just after the next voltage zero (if the positive and negative discharges are similar), and the one after this will occur before

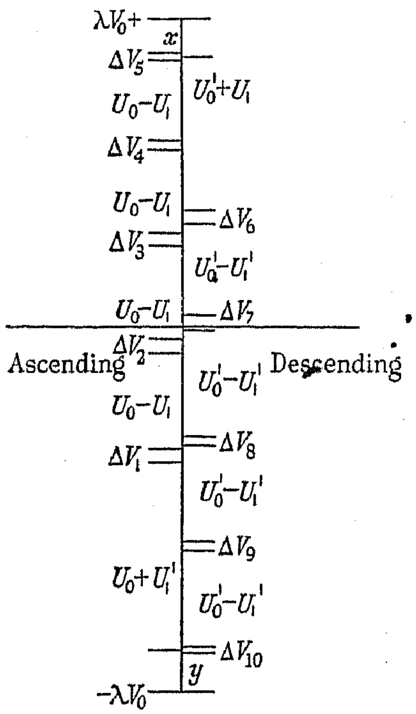

Fig. 4

the positive crest owing to the finite duration of the discharges. Thus the negative discharge will get later and the positive earlier until they are symmetrically situated in the two quarter-cycles preceding the voltage crests. As the applied voltage is further increased the discharges drop back towards the voltage zeros until a second discharge appears at a voltage crest. Two discharges will now occur per half-cycle but will drop back from the crests until symmetrically situated, since the sums of the ΔV's in either half-cycle must be equal.

If the applied voltage is reduced from U_0 the value required to start the discharge does not disappear but occurs nearer the voltage crest until $\lambda V_0 = \frac{1}{2} U_0$, when the discharge is always at the voltage crest and any further reduction of applied voltage causes its disappearance. Thus a discharge may be maintained at half the voltage required to initiate it.

• If the positive and negative discharges differ a stability of epoch may occur, provided the difference is small or provided the number of discharges is great so that the variation of ΔV with epoch is capable of compensating for the lack of integral relationship between $U_0 - U_1$ and $U_0' - U_1'$. If this compensation cannot be made then the epochs of the discharges will vary in a continuous but periodic fashion. Typical records exemplifying these phenomena are given in the paper.

It is proved by experiment and analysis that repeating discharges in a dielectric may occur at a voltage less than is required to initiate a discharge and, by analogy with the model circuit, that this voltage may be as low as one-half the initiating voltage; also that the initial discharge will probably occur on a voltage crest and repeating discharges will then take place in the quarter-cycle preceding the voltage crests or, with greater voltages, at and before the voltage zeros. By analogy with the model circuit one may further conclude that two discharges per half-cycle will occur at a voltage only slightly in excess of that needed to initiate a discharge, and that with unequal positive and negative discharge voltages the epochs at which discharges occur may vary periodically so that even one intrinsically stable source may produce apparently unstable discharges.

Tests on paper condensers showed that this method of detection of internal discharges indicated their presence at voltages of the same order as those observed with a high frequency (85 kc./s.) discharge detector.

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